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(FARNBOROUGH)

TECHNICAL NOTE No. M.E. 382

THE ATTACK OF AIRCRAFT FUSELAGES BY CONTINUOUS ROD WARHEADS

(3/16 and 1/4 inch Square - section rods)

by

R. G. E. Mallin, A. F. R. Ae. S., G.I. Mech. E.

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by et al

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SUMMARY

This Note records the results of a number of static and dynamic detonations of 3/16 and 1/4 inch square-section continuous rod (C.R.) warheads against Boeing "B.29", Vickers "Valiant", Handley Page "Victor" and some replica steel fuselage sections, most of which were either loaded to simulate straight and level flight conditions during attack and/or were subsequently loaded to determine residual strength. Rod effectiveness was found to depend, for all the targets, on the direction of rod approach to, and the construction of, the section attacked but at least for the 3/16 inch C.R., appeared to be independent of rod impact velocity in the range 3000 to 5000 f.p.s.

Stress analyses made of the damaged targets indicate that there may well be a correlation between the failing stresses in bending of fuselages of various forms of construction. Further work to confirm and extend this and other indications is proposed.

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CONTENTS

		Page
1	INTRODUCTION	8
2	OBJECTS OF THE TRIALS	8
3	TRIALS PROGRAMME	9
4	WARHEADS	9
5	TARGETS	10
6	INSTRUMENTATION	12
7	TRIALS PROCEDURE	13
8	TRIALS RESULTS	14
9	STRESS ANALYSIS OF LOADED TARGETS	17
10	DISCUSSION OF TRIALS RESULTS	17
	10.1 Loaded targets	17
	10.2 Unloaded targets	19
11	DISCUSSION OF STRESS ANALYSIS RESULTS	20
12	CONCLUSIONS	23
13	FURTHER WORK	24
14	ACKNOWLEDGEMENTS	25
REFERENCES		25
ADVANCE DISTRIBUTION		26
APPENDIX 1		31
Figs.1-8 of Appendix 1		-
APPENDIX 2		35
Tables 1-7 of Appendix 2		36-42
TABLES 1-3		27-30
ILLUSTRATIONS - Figs.1-28		-
DETACHABLE ABSTRACT CARDS		-

APPENDICES

Appendix		Page
1	- Details of target layouts and methods of loading	31
2	- Stress analysis of damaged fuselage targets	35

TABLES

Table		
1	- Summary of continuous rod firings against fuselage targets	27
2	- Details of continuous rod warheads used in lethality trials	29
3	- Summary of damage to fuselage targets	30
Appendix 2		
1	- Target No.1A, Stress analysis of 'Valiant' fuselage section	36
2	- " No.1B, " " " 'Victor' " "	37
3	- " No.2, " " " 'B.29' " "	38
4	- " No.3B, " " " 'B.29' " "	39
5	- " No.3A, " " " 'B.29' " "	40
6	- " No.4A, " " " 'B.29' " "	41
7	- " No.5A, " " " 'B.29' " "	42

ILLUSTRATIONS

	Fig.
Cross section of 'Valiant' and 'Victor' targets at attack stations	1
Cross section of 'B.29' fuselage at attack stations	2
Target 1A - Record of rod damage to 'Valiant Type 673' fuselage (1/4 in. rod)	3
" 1B - Record of rod damage to 'Victor' fuselage (1/4 in. rod)	4
" 6 - Record of rod damage to 'Victor' prototype target (1/4 in. rod)	5
" 7A - Record of rod damage to 'B.29' target (1/4 in. rod)	6
" 7B - " " " " " " " " " "	7

ILLUSTRATIONS (Continued)

			Fig.
Target	2	- Record of rod damage to 'B.29' target (1/4 in. rod)	8
"	3B	- " " " " " " " (3/16 in. rod)	9
"	3A	- " " " " " " " " " "	10
"	4A	- " " " " " " " " " "	11
"	5A	- " " " " " " " " " "	12
"	4B	- " " " " " 'SS.1' replica steel fuselage section (3/16 in. rod)	13
"	5B	- Record of rod damage to 'SS.1' replica steel fuselage section (3/16 in. rod)	14
"	8	- Record of rod damage to steel honeycomb sandwich target (3/16 in. rod)	15
"	1A	- Loaded 'Valiant' rear fuselage before attack	16a
"	1A	- Damage to rod 'entry' side of fuselage showing failure	16b
"	1A	- Damage to rod 'exit' side of 'Valiant' fuselage	16c
"	1A	- Detail of fuselage failure at the starboard side end of rod cut	16d
"	1A	- Rod behaviour near end of cut on port side of 'Valiant' fuselage	16e
"	1B	- Unloaded 'Victor' fuselage before attack	17a
"	1B	- Damage to rod 'entry' side of 'Victor' fuselage	17b
"	1B	- Damage to rod 'exit' side of 'Victor' fuselage	17c
"	1B	- Detail of rod cut end on starboard side of 'Victor' fuselage	17d
"	1B	- Rod damage to interior of 'Victor' fuselage	17e & f
"	1B	- Rod cut end after subsequent loading equivalent to '0.6g'	17g
"	1B	- Failure of 'Victor' fuselage under subsequent loading equivalent to '0.94g'	17h
"	1B	- 'Victor' fuselage after failure under subsequent loading equivalent to '0.94g'	17j & k

ILLUSTRATIONS (Continued)

		Fig.
Target 6	- Rod damage to 'Victor' rear fuselage	18a,b & c
" 7A	- Rod damage to top of 'B.29' wing/fuselage junction	19a
" 7A	- Rod 'entry' damage to wing box top surface inside 'B.29' fuselage	19b
" 7A	- Detail of rod cut end on fuselage starboard side	19c
" 7A	- Damage to rod 'exit' side of 'B.29' wing/fuselage junction	19d
" 7B	- Rod 'entry' damage to bottom of 'B.29' wing/fuselage junction	20a
" 7B	- Rod 'exit' damage to wing box top surface inside 'B.29' fuselage	20b
" 2	- Unloaded 'B.29' aft bomb bay section before attack	21a
" 2	- Damage to rod 'entry' side of 'B.29' fuselage	21b
" 2	- Damage to rod 'exit' side of 'B.29' fuselage	21c
" 2	- Starboard side of damage 'B.29' fuselage under subsequent loading	21d
" 2	- Rod damage to longeron structure	21e,f,g & h
" 2	- Damage to longerons after rod attack, severing and loading to '2.3g'	21j & k
" 3B	- Damage to rod 'entry' side of unloaded 'B.29' fuselage	22a
" 3B	- Damage to rod 'exit' side of B.29' fuselage	22b
" 3B	- Rod 'entry' side damage under subsequent loading equivalent to '2.8g'	22c & d
" 3B	- Behaviour of severed longeron members under subsequent loading equivalent to '2.8g'	22e & f
" 3A	- Damage to rod 'entry' side of '1g' loaded 'B.29' mid-crew compartment	23a
" 3A	- Detail of damage at rod cut end on starboard side	23b
" 3A	- Detail of damage at rod cut end on port side	23c
" 3A	- Damage to rod 'exit' side of fuselage	23d

ILLUSTRATIONS (Continued)

	Fig.
Target 4A - Damage to rod 'entry' side of unloaded 'B.29' mid-crew compartment	24a
" 4A - Detail of damage at rod cut end on starboard side	24b
" 4A - Detail of damage at rod cut end on port side	24c
" 4A - Damage to rod 'exit' side of fuselage	24d
" 5A - Damage to rod 'entry' side of '1g' loaded 'B.29' mid-crew compartment	25a
" 5A - Failure of fuselage under subsequent loading equivalent to '1.8g'	25b
" 5A - Damage to rod 'exit' side of fuselage after subsequent failure	25c
" 5A - Detail of failure under additional load of the compression loaded side of the fuselage	25d
Rod behaviour near ends of cut on 'B.29' fuselage sections	25e & f
Target 4B - Rod damage to water filled 'SS.1' target	26
" 5B - Rod damage to simulated equipment filled 'SS.1' target	27
" 8 - Damage to rod 'entry' side of steel honeycomb target	28a
" 8 - Rod 'exit' side damage to steel honeycomb target	28b
" 8 - Rod damage to honeycomb core and inner skin	28c
" 8 - Detail of typical rod cut end on steel honeycomb target	28d

Figs. to Appendix 1

Firing 1 - Target layout and methods of 'loading'	1
Target layout in Firing 2	2
Methods of subsequent loading of Targets 2 and 3B	3a & b
Target layout and primary target loading system used in dynamic rod firings 3, 4 and 5	4
Target layout for static firing against loaded and unloaded targets (Firing 1)	5A

Figs. to Appendix 1 (Continued)

	Fig.
Method of subsequently loading Victor target 1B	5b
Target layout for static firing against unloaded targets (Firing 2)	6a
Method of subsequently loading 'B.29' fuselage target (Firing 2)	6b
Typical target layout for dynamic warhead firings showing Target 4A tension loading gear (Firing 4)	7a
Typical target layout for dynamic warhead firings showing Target 3A compression loading gear (Firing 3)	7b
Details of typical target loading system for dynamic warhead firings (Targets 4A and 5A)	7c
3/16 in. Blue Jay rod warhead mounted on 2-stage rocket vehicle for dynamic warhead firing	7d
Method of subsequently loading 'B.29' fuselage target (Target 3B)	8a
Detail of tail support and counterbalance loading (Target 3B)	8b

1 INTRODUCTION

1.1 As a continuation of a general investigation into the effectiveness of continuous-rod (C.R.) warheads, further field trials have been made against a selection of aircraft fuselage targets, to extend and amplify the data obtained from previous trials[1,2,3]. In particular, the results of firings against certain sections of loaded Boeing B.29 fuselages[3] had shown the marginal effectiveness, under the trials conditions used, of the C.R. types at present envisaged, in defeating fuselage structure. It was considered desirable, therefore, to make additional firings against targets of different construction and under different target loading and attack conditions.

1.2 Firings were made against fuselage sections of Boeing 'B.29A', Vickers 'Valiant' Type 673, Handley Page 'Victor' second prototype aircraft, and against replica targets representative of a modern supersonic bomber and based on the Avro 730 project. Some of the targets were attacked in the unloaded condition, some loaded subsequent to attack and others loaded to level flight conditions during attack. The choice of targets was mainly dictated by their availability, but nevertheless they represent a range of materials and types of construction which may be expected in both present and future Soviet aircraft.

1.3 All the firings recorded in this Note were made at the Proof and Experimental Establishment, at either Shoeburyness or Pendine, between November 1960 and July 1962. Firings in which the Pendine long test track was used were made jointly with R.A.R.D.E.

2 OBJECTS OF THE TRIALS

2.1 The main object of the trials was to obtain further data on the effectiveness of 3/16 inch and 1/4 inch square-section continuous-rods in the attack of aircraft fuselage structures, the data being required for the assessment of conditional kill probabilities applicable to likely warhead/target engagement conditions.

Within this general objective were the following specific requirements:-

(a) To compare the results of attacks against similar targets loaded when attacked and loaded subsequent to attack.

(b) To establish the extent and nature of rod damage on fuselage structures of different types of construction and to compare their residual strengths.

(c) To determine the influence of rod impact velocity on the extent and nature of damage to fuselage targets of similar construction, and on the residual strength of the structures.

(d) To determine the effectiveness of continuous-rods against compression loaded areas of fuselages of different forms of construction.

(e) To determine the effectiveness of continuous-rods in the attack of experimental steel fuselage sections either empty or containing simulated fuel and internal equipment.

(f) To attempt a correlation of trials results by simple stress analysis methods.

3 TRIALS PROGRAMME

3.1 Since, in general, a continuous-rod projected from a G.W. warhead is equally likely to strike an aircraft fuselage at any section and from any direction, the programme of firings was designed to cover attacks from above and below against fuselage sections of varying detailed construction, e.g. bomb bay, rear fuselage etc. It was however decided that all rod strikes should impact the fuselages so as to give circumferential cuts in the structures, in order to make the damaged sections amenable to simple stress analysis.

3.2 Thirteen separate fuselage sections were attacked, involving eight warhead firings, four of which projected 1/4 inch square-section C.R's and the remaining four, 3/16 inch square-section C.R's. All the four 1/4 inch and one of the four 3/16 inch warheads were detonated statically, whilst the remainder of the 3/16 inch warheads were detonated dynamically on the Pendine long test track in order to achieve high rod striking velocities.

3.3 Of the thirteen targets, three were loaded to '1g' at the time of attack, to reproduce straight and level flight stresses at the attack station, and, where necessary, subsequently loaded to failure or to the maximum attainable load. Four targets were not loaded during attack but were subsequently loaded. The remaining six targets were not loaded, being used merely to obtain data on extent and nature of damage.

3.4 Of the loaded targets, four rear fuselages, i.e. the 'Victor', 'Valiant' and two 'B.29's', were attacked in tension loaded regions, whilst two 'B.29' bomb bays and one 'B.29' rear fuselage were attacked in normally compression loaded areas. The six unloaded targets, i.e. one 'Victor' rear fuselage, two 'B.29' centre fuselages and three steel specimens, were attacked from either above or below.

3.5 A summary of the firing programme and the results is given in Table 1.

4 WARHEADS

4.1 All firings were made using experimental models of Blue Jay, Red Dean or VR.725 warheads to project 3/16 and 1/4 inch square-section continuous-rods. The major details of these warheads are given in Table 2.

4.2 For the 1/4 inch C.R. static firings the Red Dean and VR.725 warheads were detonated at suitable distances above the ground on base plates secured to simple wooden or tubular steel structures. The stand-off distances from warhead centre to the point of first impact on most of the targets was adjusted to be 85% of the rod theoretical maximum hoop radius (M.H.R.) i.e. 32 ft stand-off for the Red Dean. Exceptionally, for reasons of target layout geometry, the target attacked by VR.725 was positioned at 80% M.H.R., i.e. 46 ft stand-off. In three of the four 1/4 inch rod firings (Nos.2, 6 and 7), the rods were ejected in the horizontal plane, and in the vertical plane for the remaining firing (No.1).

4.3 All but one firing (No.8) of the 3/16 inch Blue Jay warheads were made dynamically using the Pendine long test track. For this purpose each warhead was mounted, with its major axis vertical, at the front end of a two-stage rocket-propelled vehicle. The warheads were detonated at the end of the track,

when moving at approximately 3000 f.p.s., and ejected their hoops in a horizontal plane. The effective stand-off distance for these firings was approximately 20 ft, i.e. 85% M.H.R.

4.4 The fourth Blue Jay warhead (Firing No.8) was detonated statically, mounted on an angled baseplate secured to a simple wooden support. The rods were ejected in a plane approximately 30° to the horizontal and at a stand-off distance from the target of 20 ft.

5 TARGETS

5.1 The fuselage targets used in the trials consisted of the following:-

(a) Vickers 'Valiant Type 673'

This unique aircraft, derived from the standard 'Valiant B Mk.1' was specially designed for intruder missions involving high speed and high 'g' at low altitudes. Consequently, it was considerably stronger, structurally, than the B Mk.1. For this reason, its fuselage strength and construction (conventional skin and closely spaced Z-stringers) were considered to be similar in parts to that likely to be used in more modern supersonic medium bombers such as the Soviet 'Blinder' aircraft which C.R. warheads may be required to defeat.

For the purposes of the trial, the full-length 'Valiant 673' fuselage was assembled, complete with inner wings, and mounted in the normal flying attitude on supports under the wing roots. Dead loads were applied to the upper surface of the tailplane to reproduce the approximate level-flight bending and shear stresses at the attack station. The target was attacked at Stn.963, in the bomb bay deflector region, in mainly tension and shear loaded material, from a direction of 45° above abeam.

(b) Handley Page 'Victor'

Of the two 'Victor' targets attacked, the largest comprised the centre fuselage (Stns.263 to 1005) containing the whole of the bomb bay and the wing carry-through structure of the second prototype aircraft (Fig.17a). Construction of the bomb bay region was mainly of conventional skin and closely spaced Ω-stringer type, with longerons, and was typical of the bomb bay of a high subsonic medium bomber, occupying most of the fuselage depth. It could well be broadly similar to the bomb bay region of the Soviet 'Blinder' aircraft, particularly in view of its location behind the wing-box structure. For the firing, the section was simply supported at each end by sandbag cradles, and attacked in the unloaded condition at Stn.740, i.e. near the aft end of the bomb bay, from a direction of 45° above abeam, so that mainly tension and shear loaded structure was struck by the rod. Subsequently, the damaged fuselage was supported under the forward end and also just forward of the damaged station and then loaded by means of a downward load applied to the tail end, in order to determine its residual strength.

The second 'Victor' target was a section of the rear fuselage (Stns.967 to 1045) which had been used as a strength test specimen and had also been attacked in a previous trial[3]. Since, in the present firing, the object was merely to record the nature and magnitude of the damage, the target was simply supported on

one of its ends with its longitudinal axis vertical, and attacked, in the unloaded condition, at Stn.940.

(c) Boeing 'B.29A'

'B.29A' fuselage sections were used in the trials since they were available in limited quantity and could thus be used for comparative firings. Furthermore, the 'B.29' is of conventional construction and is considered to be broadly similar in structural features to the Soviet 'Badger' subsonic medium bomber. Two bomb bay sections (Stns.218 to 646), fitted with dummy bomb doors, were attacked, one in the forward section (Target 3B, Stn.300), and one in the rear (Target 2, Stn.566), i.e. forward and aft of the wing box structure, from a normal below direction of attack (Figs.22a and 21a respectively). Both were unloaded during attack and subsequently assembled into a complete fuselage and inner wings, and supported under the wing roots for loading. Downward loads were applied to nose and tail, as appropriate, to determine the residual strengths of the specimens.

In addition, three 'B.29' mid-crew compartments (Stns.646 to 834), aft of the bomb bay, were attacked at Stn.768, two from 45° above abeam and one from normal below (Targets 4A, 5A and 3A). Two of these targets (3A and 5A) - Figs.23a and 25a - were loaded during attack to simulate level flight stresses at the attack station and, since failure did not occur, subsequently subjected to increased loading. The remaining section (4A - Fig.24a) was attacked in the unloaded condition and later loaded to the limit of the straining gear. Two rod attacks were also made against that part of the 'B.29' fuselage incorporating the very heavy wing carry-through structure (Stns.383 to 485). As the two targets (7A and 7B, Figs.19a and 20a) were salvaged sections from previous trials they were simply supported on one end with their longitudinal axes vertical and not loaded during or after attack. Normal above and normal below directions of attack were used, at Stn.434.

(d) SS.1

This target was a replica of one version of the projected Avro 730 supersonic reconnaissance aircraft. It represented a 20 ft section of fuselage at about mid-length and just forward of the wings. It was of conventional skin, frame and closely-spaced Z-stringer construction, but built entirely of S.3 steel. It had been designed to represent an integral fuel tank, as in the 'Avro 730', but was not capable of being loaded. Two rod attacks were made against this type of target, one in which the target (No.4B - Fig.26) was filled with water to represent fuel and the other (No.5B - Fig.27) containing simulated dense internal equipment.

(e) Honeycomb sandwich target

This cylindrical target 6 ft 4 in. diameter and 7 ft 6 in. long was of steel honeycomb sandwich construction (Target No.8 - Fig.28a). It was manufactured by A.V. Roe and Co. in 1956, when the firm were investigating steel sandwich structures for the Avro 730 project. Although it is typical of a section of an aircraft, it was produced mainly to assess the design of fixtures used in its manufacture. Consequently, core to skin strength was not emphasized and may have been below standard. Construction was of 18 SWG (0.048") Rex 448

steel skins with the honeycomb core of 0.003" mild steel material. Skin joints were partly welded and partly riveted, the jointing members being of 16 SWG (0.064") DTD.171 material. The cylinder was closed by a diaphragm at one end and was mounted with its longitudinal axis vertical and resting on the open end. The attack was made transversely, at approximately 30° to normal, at mid-length. It was not suitable for loading.

5.2 Details of the layouts and methods of loading of the various targets are given in Appendix 1. General arrangement drawings of the layouts are given in Figs.1 to 4 of Appendix 1, and shown pictorially in Figs.5 to 8 of Appendix 1.

5.3 Cross-sections of each of the targets which were subjected to loading, showing the location and areas of the various structural members at the stations attacked, are given in Figs.1 and 2 of the Note.

6 INSTRUMENTATION

6.1 The extent and type of instrumentation used in the trials varied, to some degree, with each firing, but consisted essentially of equipment for the determination of rod velocities and high speed camera coverage of rod and target behaviour during and after attack. Broadly, the instrumentation may be considered separately for the static and dynamic warhead firings, as follows:-

6.1.1 Static firings

(a) In all static firings, other than that concerning the honeycomb sandwich target, the times taken for the continuous rods to travel between the point of detonation and the target were measured by micro-second counter chronometer (M.C.C.) actuated by an infra-red photo-cell directed at the warhead and a number of 'make' screens or wires secured to the target at the attack station. The rod mean velocities were then calculated using the averages of the times obtained from each channel. Striking velocities were then computed from rod retardation data and are given in Table 1.

In the remaining static firing, in which the honeycomb target was attacked, rod travel times were measured by an Argon Lamp Chronograph actuated by warhead detonation and 'break' wires spaced at intervals on the target. Mean and striking velocities were then calculated as above.

(b) In the static firing against the loaded 'Valiant' fuselage it was desired to investigate the behaviour of the C.R. hoop in the vicinity of one of the tangents to the fuselage - drawn from the point of warhead detonation. To achieve this, a searchlight illuminated translucent screen of thin plastic was used to provide a background for the rod which was photographed using a Fastax high-speed camera running at approximately 14,000 half-frames/sec. This technique was successful, as shown in Fig.16e.

(c) Other instrumentation in the static firings consisted of 16 mm cine-photographic coverage of spring-balance readings in cases where targets were loaded after attack through a cable system. Additionally, full still photographic coverage was used throughout the trials.

6.1.2 Dynamic firings

(a) In all the C.R. dynamic firings, rod mean velocities were obtained from the rod flight times measured by an Argon Lamp Chronograph actuated by warhead detonation and 'break' wires on the targets. Striking velocities were computed by R.A.R.D.E. from retardation data. The range of velocities at the targets are given in Table 1. Detailed analyses of the velocity measurements are given in separate R.A.R.D.E. reports[4,5].

(b) As in the 'Valiant' fuselage static firing, it was also desired to investigate rod behaviour in the loaded target tangent zones. The method adopted was similar to that used in the static firing except that, owing to the vertical disposition of the target, the Fastax camera was mounted on a tall tower and viewed downwards along the fuselage side towards a flash bulb illuminated white background screen laid on the ground (Figs.7a and 7b of Appendix 1). Good results were obtained in all three dynamic firings, as shown by the examples in Figs.25e and f. In each case rod velocity was in the region of 5300 f.p.s.

(c) Loaded target behaviour, both during attack and under subsequent additional loading, was recorded by Fairchild cameras running at approximately 250 frames/sec.

(d) In addition to the above instrumentation, mainly concerned with target response, the following data were recorded by, or at the request of, R.A.R.D.E., who participated jointly in the dynamic trials:-

(i) Warhead point of detonation, by means of a Fastax camera viewing - at right angles to the test track - the expected detonation zone, and running at approximately 14,000 half-frames/sec.

(ii) Rod development, by the 'Flare Path' technique using a Fastax camera viewing, through a mirror, the arc of rod projected in the direction of warhead motion. Film speed was again 14,000 half-frames/sec.

(iii) A general view of the target arena during firing, by means of an Acmade camera running at about 1000 frames/sec.

(iv) Space-time data of both primary and secondary rocket vehicles, using the magnet and coil system installed on the long test track.

(v) Warhead ignition delay, by means of a duplicated M.C.C. and fuze-timer system operated by the warhead firing current and the detonation flash.

Further details concerning the above are given in the relevant R.A.R.D.E. reports[4,5].

6.2 In all firings the instrumentation was provided and operated by the staff of either P. & E.E.(S.), P. & E.E.(P.) or R.A.R.D.E.

7 TRIALS PROCEDURE

7.1 The procedure adopted in each trial varied slightly according to whether the firing was to be static or dynamic and the targets loaded or unloaded.

However, in each firing, after assembling (where necessary) and positioning of the targets and in certain cases applying the simulated '1g' level flight loads, the warhead was detonated. The resulting damage was recorded and in cases where the loaded targets did not fail under attack they were subjected to additional incremental loads until failure occurred or a limiting load was reached. In the four cases where unloaded fuselage targets were subsequently loaded, the damaged portions were assembled into complete fuselages and then subjected, firstly, to the level flight loading and then, where necessary, to increased loading up to failure or, again, until a limiting load was reached. In all cases the maximum attainable loads were noted or the residual strengths of the targets determined.

8 TRIALS RESULTS

8.1 The conditions under which each firing was made are given in Table 1, and the damage to each of the fuselage targets from rod attack is summarised in Table 3, shown diagrammatically in Figs.3 to 15, and illustrated in Figs.16 to 28.

8.2 Fuselage failing loads, where applicable, and the residual strengths of the loaded targets are detailed in Table 1.

8.3 The results of the trials, in terms of lethality, may be summarised as follows:-

Firing and target No.	Rod size and velocity	Direction of attack	Target and attack stn.	Loading	Assessment	Remarks
1A	$\frac{1}{4}$" sq. low velo.	45° above abeam	'Valiant 673' rear fuselage Stn.963	'1g' on attack	Lethal	Failed on attack.
1B	$\frac{1}{4}$" sq. low velo.	45° above abeam	'Victor proto.' bomb bay Stn.740	Zero on attack subsequently loaded	Lethal	Failed at '0.9g' on loading after attack.
6	$\frac{1}{4}$" sq. low velo.	45° above abeam	'Victor proto.' rear fuselage Stn.940	None	Probably lethal	Assessment based on comparison with previous target (1B).
7A	$\frac{1}{4}$" sq. low velo.	Normal above	'B.29' fuselage at wing junction Stn.434	None	Not lethal	Assessment based on presence of heavy wing/fuselage attachment structure.
7B	$\frac{1}{4}$" sq. low velo.	Normal below	'B.29' fuselage at wing junction Stn.434	None	Not lethal	Assessment based on expected butting of damaged longeron compression members.
2	$\frac{1}{4}$" sq. low velo.	Normal below	'B.29' fuselage rear bomb bay Stn.566	Zero on attack subsequently loaded	Not lethal	No failure in subsequent loading to '2.3g'.
3B	3/16" sq. high velo.	Normal below	'B.29' fuselage forward bomb bay, Stn.300	Zero on attack subsequently loaded	Non lethal	No failure in subsequent loading to '2.8g'.
3A	3/16" sq. high velo.	Normal below	'B.29' mid-crew compartment Stn.768	'1g' on attack subsequently loaded	Non lethal	No failure in subsequent loading to '2.0g'.

Firing and target No.	Rod size and velocity	Direction of attack	Target and attack stn.	Loading	Assessment	Remarks
4A	3/16" sq. high velo.	45° above abeam	'B.29' mid-crew compartment Stn.768	Zero on attack subsequently loaded	Not lethal	No failure in subsequent loading to '2.1g'.
5A	3/16" sq. high velo.	45° above abeam	'B.29' mid-crew compartment Stn.768	'1g' on attack subsequently loaded	Not lethal	Failed at '1.8g' in subsequent loading.
4B	3/16" sq. high velo.	Symmetrical target	Steel replica fuselage mid-length	None	Probably lethal	Based on extent of hydraulic pressure wave damage in compression loaded structure. (Fuselage filled with water.)
5B	3/16" sq. high velo.	Symmetrical target	Steel replica fuselage mid-length	None	Probably not lethal	Based on only 83% of 'visible' arc cut. (Fuselage filled simulated equipment.)
8	3/16" sq. low velo.	Symmetrical target	Steel honeycomb fuselage mid-length	None	Probably not lethal	Based on only 71% of 'visible' arc cut. (Fuselage empty.)

NOTE:- The assessments relate to the probability of structural failure of the fuselage targets in bending, and assume a Category 'K' (15 second kill) standard of judgement.

9 STRESS ANALYSIS OF LOADED TARGETS

9.1 In order to obtain as much technical information as possible from full-scale trials of the type considered in this Note, and with the expectation of devising 'damage laws' for use in C.R. warhead lethality assessments, data on the maximum stresses achieved in damaged structures subjected to loads, either during or after attack, are being collected. The intention is to make a full investigation of the subject when further evidence has been obtained. Thus, in all recent trials in which fuselage specimens were loaded to establish their residual strength, the apparent maximum tensile and compressive stresses developed in the damaged structures at failure (or at maximum achievable loading) have been calculated. These stresses normally occurred at the extremities of the rod cuts, but in some attacks from 'below' the aircraft they occurred in heavy longeron members which were not completely severed and which effectively butted under load.

9.2 Concerning the trials recorded in this Note, stress analyses have been made of the seven fuselage targets which were either loaded during attack and/or subsequently loaded. The method of analysis used is similar to that employed by most aircraft manufacturers for the simple stressing of a fuselage in pure bending. In the case of the 'Valiant' and 'Victor' targets the manufacturers themselves were consulted, and for the 'B.29' targets the method was that used by the Boeing Airplane Co. in the design of the 'B.29', as noted in a U.S. report[6].

9.3 The analyses were confined to pure bending since visual examination of failed targets showed no evidence of shear failure or of torsional effects due to asymmetric damage. Frame damage was neglected because of its minor nature in the purely circumferential cuts inflicted in the trials. Rod 'exit' damage was also neglected because, although quite substantial in the dynamic warhead firings against empty fuselage sections, it appeared to have little or no effect on the mode of failure or on the maximum stresses achieved and, furthermore, would be a rare occurrance in modern aircraft fuselages densely filled with bombs, fuel or equipment.

Details of the stress analyses relating to the seven loaded targets are given in Appendix 2.

10 DISCUSSION OF TRIALS RESULTS

10.1 Loaded targets

10.1.1 The two attacks against the '1g' loaded 'Valiant' and the subsequently loaded 'Victor' aircraft (Targets 1A and 1B) showed that the $\frac{1}{4}$ in. C.R., at the low impact velocity of about 3400 f.p.s., was capable of defeating, from the 45° above abeam direction, the rear fuselages of aircraft employing closely spaced stringer construction typical of modern subsonic and low super-sonic bombers (Figs.16b and c, 17h, j and k). It may be inferred that the rods would be equally effective at any attack direction from normal above to 45° on either side of this position.

On the other hand, the 3/16 in. C.R. was incapable, in two attacks (Targets 4A and 5A), of defeating the rear fuselage of the 'B.29' from the 45°

above abeam approach direction and at a striking velocity of approximately 5100 f.p.s. (Figs.24a, b, c and d, 25a). This may be largely due to the relative toughness of the B.29's widely spaced extruded stringer construction as shown by a comparison between similar fuselage sections of the 'Valiant' and the 'B.29' (Stns.963 and 566 respectively). In the 'Valiant' section a level flight bending moment of approximately 7.5×10^6 lb in. is taken by a cross-sectional area of about 39 in.^{2} whereas the 'B.29' section bending moment of 4.75×10^6 lb in. is supported by as much as 31.4 in.^{2} of material.

10.1.2 Three attacks against forward and rear bomb bay sections, and a rear fuselage section, of the B.29 (Targets 3B, 2 and 3A), showed that neither the $\frac{1}{4}$ in. C.R. at approximately 3400 f.p.s. nor the 3/16 in. C.R. at approximately 5100 f.p.s., were capable of causing fuselage failure in attacks from normal below, under level flight loads. In two attacks the longeron members were not completely severed (Figs.21e and g, 23a) and butting of the damaged sections occurred, whilst in the other case (Target 3B) the longerons were completely severed but even so butting still took place, and persisted despite the application, eventually, of a fluctuating load (Figs.22e and f).

It would appear from these results that the 3/16 and $\frac{1}{4}$ in. C.R's are unlikely to prove effective against compression loaded fuselage structure incorporating relatively heavy extruded stringers or longerons and may only be effective against light skin and sheet stringer structure under compression loading.

10.1.3 The results of the two 3/16 in. rod attacks (Targets 4A and 5A) made against similar sections of the B.29 rear fuselage under similar attack conditions, except for the loading, (Figs.24a and 25a), showed that the residual strength of a target attacked in the unloaded condition and subsequently loaded could be up to 17% greater than one attacked in the loaded condition, even though slightly less structure was severed in the target loaded during attack. It is evident that this indication should be investigated so that due allowance can be made when using the results of unloaded trials for assessment purposes. The magnitude of the difference cannot, at present, be even approximately estimated since identical structures can show considerable variations in strength and the nature of rod damage is not always consistent under similar attack conditions.

10.1.4 It was intended that the effects of increased rod striking velocity should be shown by comparison of the results of two attacks, Target No.5A and Firing No.2 of Ref.3 against similar sections of the B.29 rear fuselage. Unfortunately, the high velocity rod impact (Fig.25a) resulted in a continuous cut some 13° of arc smaller, and cutting approximately 3% less material of the 'attack' side, than the corresponding low velocity strike. Hence, the residual strengths of the two targets corresponded to '1.8g' and '1.5g' loadings, for the high and low velocity strikes, respectively. That this lower order of damage was not typical of high velocity impacts was shown by the results from Target No.4A against a similar B.29 section, where the rod 'entry' damage (Fig.24a) was virtually identical to that in the low velocity firing. However, the residual strengths of these targets are not strictly comparable because of the differing loading conditions during attack.

10.1.5 Although, from these few firings it is difficult to estimate the effect on fuselages of rod striking velocity, it must be noted that neither in Target 4A nor 5A did the higher striking velocity produce more rod 'entry' damage than the lower velocity strike. Rod 'exit' damage was, however, found to be consistently greater for the high velocity impacts on nearly empty targets.

10.1.6 It is also worth noting, at this point, that no 3/16 in. C.R. attack of a fuselage target, either described in this Note or previously reported[3], under a variety of attack conditions, has been found capable of defeating the target under '1g' level flight loading.

10.1.7 All but two attacks of the loaded targets produced values of 'arc of rod cut to arc visible' of greater than 90%, the exceptions being high-velocity strikes (Targets 3A and 5A), where there was evidence of breaks in the rod hoop occurring near the ends of the rod cut on the target, thus reducing the rates of 'arc cut' to 'arc visible' to 80% and 83% respectively.

10.1.8 All the seven attacks of loaded targets, except Target 2, where heavy longerons were present, give percentages of structural material severed in the rod 'entry' surface to that of the cross-sectional area of the whole section varying only between 33% and 37%. This result is perhaps surprising in view of the different trials conditions involved such as target construction, direction of attack, rod striking velocity etc. If both rod 'entry' and 'exit' damage are added, then the percentage of the total cross-sectional area of the section cut by the rod rises to between 41% and 53%. This much larger variation seems to be independent of the attack conditions and is probably attributable to the widely differing quantity and location of internal equipment and secondary structure within the various targets, all of which affects the 'exit' damage considerably.

10.2 Unloaded targets

10.2.1 The results of Firing No.6 against the 'Victor' rear fuselage largely confirmed the result obtained from the secondary target in Firing No.1 of Ref.3, in that all the rod 'entry' side structure, such as skin, closely spaced stringers and longeron members, within the 155° arc of cut, was severed. In addition, it showed that the arc of rod cut as a percentage of arc visible, i.e. 91%, was of the same order as obtained on circular fuselage sections employing other forms of light-alloy construction. Rod 'exit' damage, however, was considerable, in the absence of the strong structural members near the fuselage centre line which were present in the earlier firing, and accounted for approximately one third of the total structural cross-sectional area severed (Figs.5 and 18).

10.2.2 The damage to Targets 7A and 7B showed conclusively that $\frac{1}{4}$ in. C.R's, after passing through either the top or bottom fuselage skins of a B.29 wing/fuselage junction, were incapable of severely damaging the wing box structure, largely due to rod break-up on the fuselage 'entry' skinning (Figs.19b and 20b). In both attacks structure severed on the rod 'entry' side could account for no more than 15-20% of the total structural cross-sectional area as compared with some 35% commonly obtained on cylindrical shell target sections. Consequently, neither of these two attacks could be assessed as

fuselage structural kills because of the very heavy wing carry-through structure which, since only lightly damaged, would probably be capable of carrying fuselage loads transmitted to it by the severance of fuselage skinning. This assessment is, of course, confined to the fuselage and does not consider the effects of spanwise damage to the inner wings which would inevitably occur in practice with this type of attack.

10.2.3 Both firings against steel cylindrical sections (Targets 4B and 5B) having very closely spaced stringers showed a relatively low percentage of 'arc of rod cut to arc of target visible', being about 83 to 85% as compared with the normal for light alloy targets of over 90%. This may well be accounted for by the comparatively higher resistance to the rod of the stringers near the point of tangency despite the high impact velocity. This is supported by the clear evidence of the gradually decreasing damage to the 10 or so stringers just before the end of the rod cut in the skin.

In the case of the water-filled target (No.4B) the damage (Figs.13 and 26) was such that, had it been in a mainly tensile loaded region, the aircraft might possibly have survived longer than the 15 seconds required for a Cat.'K' kill, owing to the relatively low arc of cut. Had it occurred in a mainly compression loaded region, however, the result would probably have been catastrophic.

In the attack of the target (No.5B) with simulated equipment, no exit damage was produced and since the arc of cut on the target at rod entry was restricted to 132° and severed only 36% of the total cross-sectional area (Fig.27), it seems likely that the target would have survived whether the damage had been in tension or compression loaded material.

10.2.4 The single attack against the target (No.8) of steel honeycomb construction yielded the unusually low ratio of 'arc cut to arc visible' of 71%. Examination of the damage (Fig.28) showed this to be due to the bunching-up of the honeycomb core between the steel skins at the rod cut extremities. This presented a very solid barrier to further progress of the rod, and probably caused it to break prematurely. It was also noted that the cut skins of the target exhibited a marked degree of petalling (Fig.28c) particularly on the inner skin, a phenomenon which did not occur with light-alloy skins under either low or high velocity rod impact nor on the steel skin and stringer target in Firing 5B (Fig.27).

11 DISCUSSION OF STRESS ANALYSIS RESULTS

11.1 In order to indicate the nature of the evidence which is being obtained from the stress analyses, the results from the seven loaded target trials covered in this Note and five results from earlier trials[3,7], are discussed.

11.2 The approximate maximum stresses, neglecting possible stress-concentration effects, occurring at failure or at maximum achievable loading, in the seven loaded specimens of this Note, were found to be as follows:-

Target No.	Target aircraft	Target station	Rod size in. x in.	Direction of attack	Approx. rod striking velocity f.p.s.	Loading condition	Maximum stress lb/in.^{2}	
							Tensile	Compressive
1A	Valiant	963	½ x ½	45° above abeam	3450	At failure during attack at 1g	28,800	10,000
1B	Victor	740	½ x ½	45° above abeam	3450	At failure under 0.94g loading	19,100	7,850
4A	B.29	768	3/16 x 3/16	45° above abeam	5000	Under 1g loading after attack	9,060	5,590
						Under max. loading of 2.1g*	19,650	12,000
5A	B.29	768	3/16 x 3/16	45° above abeam	5100	Under 1g loading after attack	9,740	5,870
						At failure under 1.8g loading	16,450	9,900
3A	B.29	768	3/16 x 3/16	Normal below	5100	Under 1g loading after attack	4,925	7,710
						Under max. loading of 2g*	9,570	14,950
2	B.29	566	½ x ½	Normal below	3380	Under 1g loading after attack	6,920	9,040
						Under max. loading of 2.3g*	16,200	21,200
3B	B.29	300	3/16 x 3/16	Normal below	5200	Under 1g loading after attack	4,525	8,180
						Under max. loading of 2.8g*	12,840	23,200

* Failing loads could not be attained in these tests

11.3 Combining the current and earlier trials, eight of a total of 12 results involved normally tensile loaded structure, whilst the remaining four involved compression loaded material. Since the mode of failure of tensile and compressive loaded structure is quite different, they must be considered separately.

11.4 The calculated maximum tensile stresses are noted first, and are as follows:-

Target or firing No.	Rod size and velocity	Target aircraft	Fuselage station	Attack condition	Calculated maximum tensile stress lb/in.^{2}		
					At failure under attack	At failure under increased load	At maximum load applied
1A	½" L.V.	Valiant	963	Loaded	28,800	-	-
1B	½" L.V.	Victor	740	Unloaded	-	19,100	-
4A	3/16" H.V.	B.29	768	Unloaded	-	-	19,650 (No failure)
5A	3/16" H.V.	B.29	768	Loaded	-	16,450	-
1	½" L.V.	B.29*	768	Loaded	11,500	-	-
2	3/16" L.V.	B.29*	768	Loaded	-	16,400	-
3	½" L.V.	B.29*	566	Loaded	-	22,600	-
4	5/16" L.V.	B.29*	566	Loaded	25,500	-	-

* Data from Ref.3

11.5 From the four cases where fuselage failure occurred on gradually increasing the loading it appears that the range of failing stress could be from about 16,000 to 23,000 lb/in.^{2}. This is not contradicted by the single case where no failure occurred at a stress of 19,650 lb/in.^{2}, since this target was unloaded during attack and might therefore be expected to have a somewhat higher residual strength. Furthermore, it was not possible at the time to continue the loading to a stress level of around 23,000 lb/in.^{2}. Of the three targets which failed during attack, two probably failed under stresses considerably lower than the 'apparent' maximum values calculated. The remaining target, however, failed at the exceptionally low nominal stress of 11,500 lb/in.^{2}, some 5000 lb/in.^{2} less than the maximum stress values of two similar targets which failed during increased loading after the attacks. This low-stress result, obtained from the first rod warhead firing against a loaded fuselage target conducted in the U.K., could be due to inexperience, at that time, in determining precisely the extent of rod damage in targets which failed under attack. This isolated result should, therefore, be treated with reserve.

11.6 From the few results available so far, the broad indications are that for C.R. attacks against tensile-loaded surfaces of cylindrical semi-monocoque fuselages employing different forms of construction, the fuselages are liable to fail if the calculated maximum tensile stresses, in the damaged section, equal or exceed the following values:-

(a) 16,000 lb/in.^{2} for skin, frame and light extruded stringer construction.

(b) 17,000 lb/in.^{2} for skin, frame and closely spaced sheet stringer construction.

(c) 22,000 lb/in.^{2} for skin, frame and widely spaced heavy extruded stringer construction.

At present, these must be regarded as tentative deductions. Nevertheless they are thought to be reasonable in view of the narrowness of the band of stress values covering the three types of structure so far investigated.

11.7 In all, four attacks have been made against fuselage compression loaded surfaces. The calculated maximum compressive stresses achieved are as follows:-

Target or firing No.	Rod size and velocity	Target aircraft	Fuselage station	Attack condition	Calculated maximum compressive stress lb/in.^{2}	
					At failure under applied load	At maximum load achievable
3A	3/16" H.V.	B.29	768	Loaded	-	14,950 } No failure
2	¼" L.V.	B.29	566	Unloaded	-	21,200 } No failure
3B	3/16" H.V.	B.29	300	Unloaded	-	23,200 } No failure
1	¼" L.V.	B.29*	566	Unloaded	29,750	-

* Data from Ref.7

11.8 These results, although consistent, are too few for even tentative deductions to be made at this stage, particularly in view of the probably wider band of failing stress values than for the tension loaded surfaces. It appears, both from the compressive stress values and from the behaviour of the targets under the maximum achievable loads, that the stress for failure will increase considerably where longerons are present. This could be due to the difficulty experienced by C.R's in cutting completely all the members of a built-up section and hence the high probability of butting of semi-severed structure.

11.9 Using the estimated failing stress values obtained by the foregoing method, and in conjunction with theoretical analyses of the influence of direction of attack on the maximum stresses in rod-damaged fuselages of different types of construction[11], it should, eventually, be possible to predict, with fair accuracy, the results of C.R. strikes on likely target aircraft. At present, accuracy is limited by the relatively few trials results, the few types of construction investigated and the simple attack conditions so far considered.

12 CONCLUSIONS

12.1 The following general indications may be deduced from the results of the trials described in this Note and, in certain cases, from consideration of the results of previous work[3]:-

(a) The $\frac{1}{4}$ in. C.R. should be capable of causing failure in level flight of the rear fuselage of a modern subsonic or low supersonic bomber, employing closely spaced light alloy stringer and skin construction, when attacking from above.

(b) Neither the $\frac{1}{4}$ in. C.R. at low impact velocity, nor the 3/16 in. C.R. at high impact velocity, appears capable of causing failure in level flight of

the entire lower half, nor the centre section upper half, of the fuselage of a subsonic bomber of similar construction to the Boeing 'B.29'.

(c) The 3/16 in. C.R. even at high impact velocity, may be incapable of causing failure in level flight of a supersonic (M2 to 3) bomber fuselage of steel skin and closely spaced stringer construction, except for strikes on integral fuel tank sections containing fuel.

(d) There is evidence that steel honeycomb fuselage structure, typical of high supersonic aircraft, may be appreciably more resistant to C.R. attack than consideration of the structure might suggest.

12.2 In addition, the following specific points arise from the trials:-

(a) No significant difference has been found in the extent and nature of rod 'entry' damage from 3/16 in. C.R's impacting similar targets at approximately 3200 f.p.s. and 5200 f.p.s., although rod 'exit' damage was greater for the high velocity impacts on virtually empty targets.

(b) The compression-loaded under-surfaces of fuselages were found to be capable of withstanding attack, because of the liability to butting of the damaged material, which occurred even when relatively light longeron members were severed.

(c) The residual strengths of targets attacked by C.R. in the loaded condition are likely to be considerably less than those of targets attacked in the unloaded condition and subsequently loaded.

12.3 A simple bending stress analyses of loaded targets, as described in this Note, if used in conjunction with studies of the influence of direction of attack on maximum stresses in damaged targets of various forms of construction, should - when more data become available - enable fair estimates to be made of the results of actual C.R. attacks against likely types of aircraft targets.

13 FURTHER WORK

13.1 The work described in this Note has, by its limited nature, revealed only indications and trends likely to be important in the attack of fuselage structures by C.R's. It is necessary that further trials should be made to confirm and extend these indications. These might include:-

(a) Firings of 3/16 in. and $\frac{1}{4}$ in. C.R. against loaded sections of fuselage structures of various types in order to obtain more data on the behaviour of the different forms of construction, in particular those in steel. Stress analyses of such firings should provide a better understanding of the failing stresses of structures damaged by C.R's.

(b) Firings of $\frac{1}{4}$ in. C.R's at high velocity against fuselage structures to determine whether the performance of this size of rod is enhanced by higher impact velocity.

(c) Firings of C.R's against fuselages such as to produce more complex attack conditions, e.g. angled cuts etc.

13.2 In addition, it is considered that the investigation on the influence of direction of attack on the stresses in a damaged fuselage, commenced in Ref.11, should be extended to other fuselages of different construction in order that present and future trials results may become more generally applicable to various potential targets and also may be used with greater confidence.

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ATTACHED:-

Appendices 1 and 2
Tables 1-3
Figs.1-15 - Drg. Nos. SME 88679/R to SME 88694/R
Figs.16-28 - Neg. Nos. 164007 to 164035
Detachable abstract cards

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TABLE 1 - Summary of continuous-rod firings against fuselage targets

Firing and target No.	Rod cross-section in. × in. and type of trial	Direction of rod approach	Stand off distance ft	Rod mean velocity f.p.s.	Estimated rod striking velocity f.p.s.	Target	Attack station	Target loading during attack	Result of attack	Target loading after attack
1A	$\frac{1}{4} \times \frac{1}{4}$ static	45° above abeam	32	3663	3450	Vickers Valiant B Mk.2 rear fuselage See Fig.1a	963	1g flight loads 27,216 lb at Stn.1210 giving B.M. = 7,660,000 lb in. S.F. = 31,540 lb at Stn.963	Fuselage failed see Fig.16	
1B	$\frac{1}{4} \times \frac{1}{4}$ static	45° above abeam	32	3663	3450	Handley Page Victor prototype bomb bay See Fig.1b	740	Unloaded	See Fig.17	Subsequently loaded by applying 21,280 lb at Stns.972 and 1005 giving B.M. = 5,680,000 lb in. S.F. = 25280 lb at Stn.740 equivalent to 0.94g. <u>FUSELAGE FAILED</u>
6	$\frac{1}{4} \times \frac{1}{4}$ static	45° above abeam	46	3700(E)	3500	Handley Page Victor prototype rear fuselage	940	Unloaded	See Fig.18	None
7A	$\frac{1}{4} \times \frac{1}{4}$ static	Normal above	30	3700(E)	3500	Boeing B.29A wing/ fuselage junction	434	Unloaded	See Fig.19	None
7B	$\frac{1}{4} \times \frac{1}{4}$ static	Normal below	30	3700(E)	3500	Boeing B.29A wing/ fuselage junction	434	Unloaded	See Fig.20	None
2	$\frac{1}{4} \times \frac{1}{4}$ static	Normal below	32	3591	3380	Boeing B.29A rear bomb bay See Fig.2c	566	Unloaded	See Fig.21	Subsequently loaded by applying 18,368 lb at Stn.1059 giving B.M. = 11,160,000 lb in. S.F. = 25,710 lb at Stn.566, equivalent to 2.3g. <u>FUSELAGE DID NOT FAIL</u>
3B	3/16 × 3/16 dynamic	Normal below	32 true 20 effective	5500 min.(E) 5975 max.	5030 min. 5459 max.	Boeing B.29A forward bomb bay See Fig.2a	300	Unloaded	See Fig.22	Subsequently loaded by applying 23,605 lb at Stns.50 and 191 giving B.M. = 6,175,700 lb in. S.F. = 29,200 lb at Stn.300, equivalent to 2.8g. <u>FUSELAGE DID NOT FAIL</u>

TABLE 1 (Continued)

Firing and target No.	Rod cross-section in. × in. and type of trial	Direction of rod approach	Stand off distance ft	Rod mean velocity f.p.s.	Estimated rod striking velocity f.p.s.	Target	Attack station	Target loading during attack	Result of attack	Target loading after attack
3A	3/16 × 3/16 dynamic	Normal below	33.2 true 20 effective	5335 min. 5900 max.(E)	4860 min. 5410 max.	Boeing B.29A mid-crew compartment See Fig.2b	768	1g flight loads, 8600 lb at Stn.1050 giving B.M. = 2,420,000 lb in. S.F. = 8600 lb at Stn.768	Fuselage did not fail See Fig.23	Load increased to 16,600 lb at Stn.1050 giving B.M. = 4,700,000 lb in. S.F. = 16,600 lb at Stn.768, equivalent to 2.0g. FUSELAGE DID NOT FAIL
4A	3/16 × 3/16 dynamic	45° above abeam	33.5 true 20 effective	5264 min. 5733 max.	4850 min. 5260 max.	Boeing B.29A mid-crew compartment See Fig.2b	768	Unloaded	See Fig.24	Subsequently loaded by applying 17,679 lb at Stn.1050 giving B.M. = 4,980,000 lb in. S.F. = 17,679 lb at Stn.768, equivalent to 2.1g. FUSELAGE DID NOT FAIL
5A	3/16 × 3/16 dynamic	45° above abeam	33.5 true 20 effective	5354 min. 5813 max.	4900 min. 5300 max.	Boeing B.29A mid-crew compartment See Fig.2b	768	1g flight loads, 8864 lb at Stn.1050 giving B.M. = 2,495,000 lb in. S.F. = 8864 lb at Stn.768	Fuselage did not fail See Fig.25	Load increased to 14,884 lb at Stn.1050 giving B.M. = 4,210,000 lb in. S.F. = 14,884 lb at Stn.768, equivalent to 1.8g. FUSELAGE FAILED
4B	3/16 × 3/16 dynamic	Symmetrical target	33.5 true 20 effective	5264 min. 5733 max.	4850 min. 5260 max.	SS.1 steel replica fuselage section	Mid-length	Unloaded but filled with water	See Fig.26	None
5B	3/16 × 3/16 dynamic	Symmetrical target	33.5 true 20 effective	5354 min. 5813 max.	4900 min. 5300 max.	SS.1 steel replica fuselage section	Mid-length	Unloaded but filled with simulated equipment	See Fig.27	None
8	3/16 × 3/16 static	Symmetrical target	20	3550	3390	Steel honeycomb sandwich fuselage section	Mid-length	Unloaded	See Fig.28	None

'E' denotes an estimated rod velocity in cases where recordings were incomplete

'min.' and 'max.' denote minimum and maximum rod velocities recorded on the targets in the dynamic firings

TABLE 2 - Details of continuous-rod warheads used in the trials

Firing Nos.	Warhead type	Warhead weight lb	Warhead length in.	Warhead diameter in.	Rod size in. x in.	Rod arrange-ment	Theoretical max. hoop rad. (M.H.R.)	Liner dia. in.	H.E. filling	H.E. filling weight lb
3,4,5,8	Blue Jay Type 1C (Solid)	48	10.9	8.0	3/16 x 3/16	2-tier	23.5	3.8	RDX/TNT: 60/40	9
1,2 & 7	Red Dean (Solid)	125	14.8	10.5	½ x ¼	2-tier	37.3	5.12	RDX/TNT: 60/40	25
6	VR.725 (Solid)	219	16.5	14.25	½ x ¼	2-tier	57.5		RDX/TNT: 60/40	50

All statically detonated warheads were initiated by a centrally positioned No.33 electric detonator and a 14 dram CE pellet

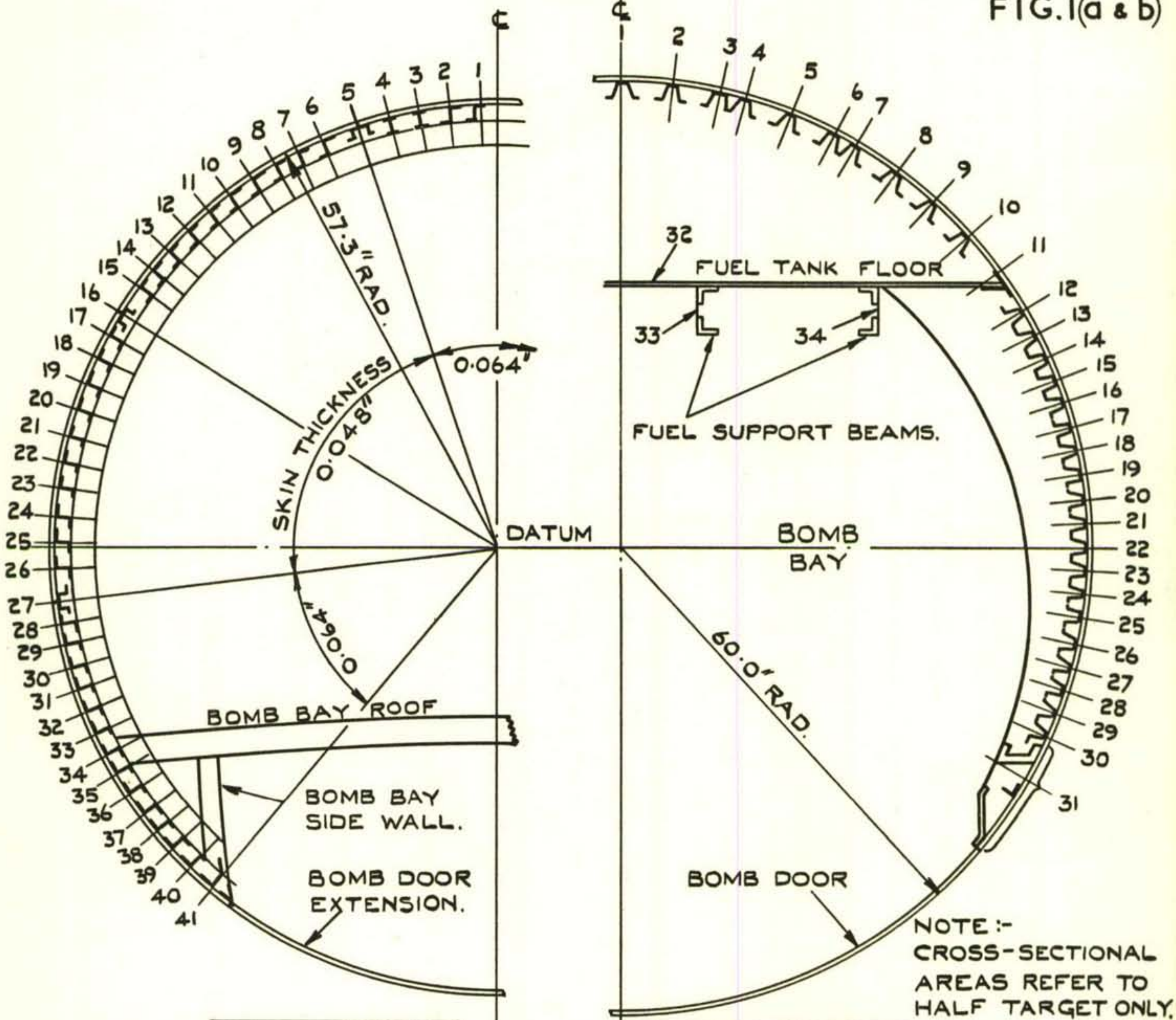
All dynamically detonated warheads were initiated by a centrally positioned ICI seismic detonator

TABLE 3 - Summary of rod damage to fuselage targets

Firing and target No.	Rod cross-section in. × in.	Direction of rod approach	Target	Arc of fuselage visible from warhead position (A)°	Actual arc of strike on fuselage	Percentage B/A %	Total fuselage structural cross-sectional area $in.^2$	Approx. percentage of total fuselage structural C.S.A. severed on entry side %	Approx. percentage of total fuselage structural C.S.A. severed on entry side + exit side %	Additional structure severed	Result
1A	$\frac{1}{4} \times \frac{1}{4}$ (L.V.)	45° above abeam	Stn.963 Valiant fuselage	165	151[1]	92	38.8	37	45	1 frame	Fuselage failed on attack under '1g' loading
1B	$\frac{1}{4} \times \frac{1}{4}$ (L.V.)	45° above abeam	Stn.740 Victor fuselage	164	151	92	35.8	36	53	1 frame	Fuselage failed under '0.94g' loading
6	$\frac{1}{4} \times \frac{1}{4}$ (L.V.)	45° above abeam	Stn.940 Victor fuselage	170	155	91	35.4	40	62	1 frame	Not loaded
7A	$\frac{1}{4} \times \frac{1}{4}$ (L.V.)	Normal above	Stn.434 B.29 fuselage	134	134	100	78.6	20	33	None	Not loaded
7B	$\frac{1}{4} \times \frac{1}{4}$ (L.V.)	Normal below	Stn.434 B.29 fuselage	130	130	100	67.1	15	20	None	Not loaded
2	$\frac{1}{4} \times \frac{1}{4}$ (L.V.)	Normal below	Stn.566 B.29 fuselage	166	161	97	31.4	27	41	1 frame	Fuselage did not fail under '2.3g' loading
3B	3/16 × 3/16 (H.V.)	Normal below	Stn.300 B.29 fuselage	158	147	93	27.4	33	44	None	Fuselage did not fail under '2.8g' loading
3A	3/16 × 3/16 (H.V.)	Normal below	Stn.768 B.29 fuselage	161	128[2]	80	27.3	35	43	None	Fuselage did not fail under '2g' loading
4A	3/16 × 3/16 (H.V.)	45° above abeam	Stn.768 B.29 fuselage	161	146	91	27.1	36	47	2 frames	Fuselage did not fail under '2.1g' loading
5A	3/16 × 3/16 (H.V.)	45° above abeam	Stn.768 B.29 fuselage	161	134	83	27.1	33	41	2 frames	Fuselage failed under '1.8g' loading
4B	3/16 × 3/16 (H.V.)	Symmetrical target	Mid-length SS.1 steel replica	160	136	85	36.1	36	36	4 frames	Not loaded
5B	3/16 × 3/16 (H.V.)	Symmetrical target	Mid-length SS.1 steel replica	160	132	83	36.1	36	36	1 frame	Not loaded
8	3/16 × 3/16 (L.V.)	Steel honeycomb target	Mid-length	165	117	71	26.6	28	32	None	Not loaded

NOTES:-
1 - Including 25° break
2 - Break in rod hoop before impact

L.V. - Low velocity rod strike ≏ 3400 f.p.s.
H.V. - High velocity rod strike ≏ 5100 f.p.s.



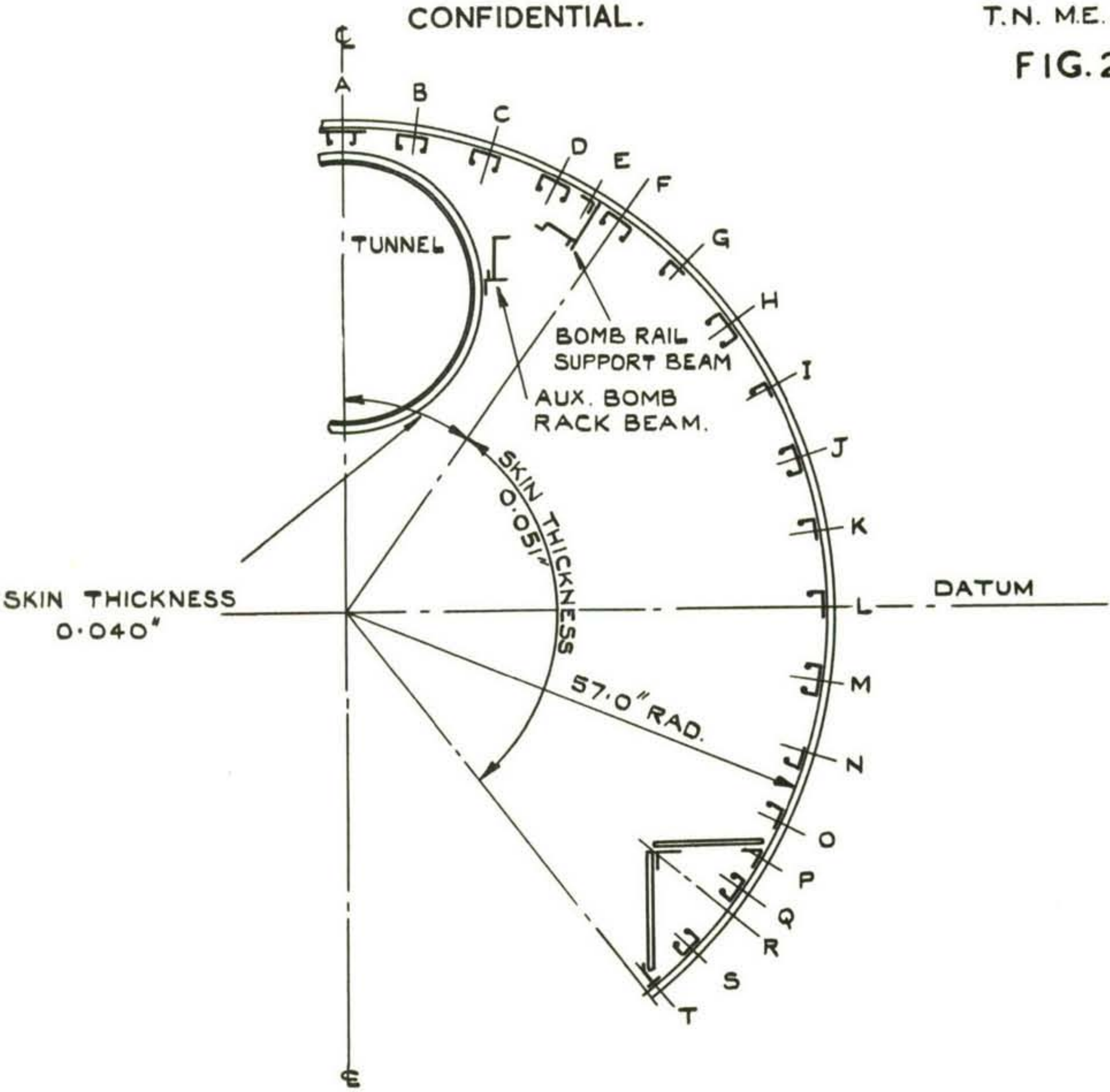
STRUCTURAL MEMBERS	CROSS-SECTIONAL AREA IN²
1, 2	0·117
3, 4	0·70
5, 16, 27	0·301
6–15	0·122
17–26, 28–32	0·128
33–40	0·173
41	4·60
SKIN (0·048")	3·80
SKIN (0·064")	3·93

STRUCTURAL MEMBERS	CROSS-SECTIONAL AREA IN²
2	0·409
3, 22, 30	0·218
11	0·201
4–10, 12–21	0·177
24, 26, 28	0·177
23, 25, 27, 29	0·102
31 + SKIN	5·7
32	1·344
33, 34	0·912
SKIN 0·036" 0·048"	5·044

1 (a) STN. 963
VICKERS 'VALIANT TYPE 673'
(TARGET 1A)

1 (b) STN. 740
HANDLEY PAGE 'VICTOR 2ND PROTOTYPE'
(TARGET 1B)

FIG. 1 (a & b) HALF-SECTIONS OF 'VALIANT' AND 'VICTOR' FUSELAGES AT ATTACK STATIONS.



STRUCTURAL MEMBERS	CROSS-SECTIONAL AREA SQ.IN.
R	0·940
T	0·864
P	0·732
A	0·402
B.F.Q.S.C.	0·395
H.J.M.	0·301
D	0·198
K.L.N.O.	0·173
E.G.I.	0·122
SKIN (0·051")	5·38
SKIN (0·040")	1·43

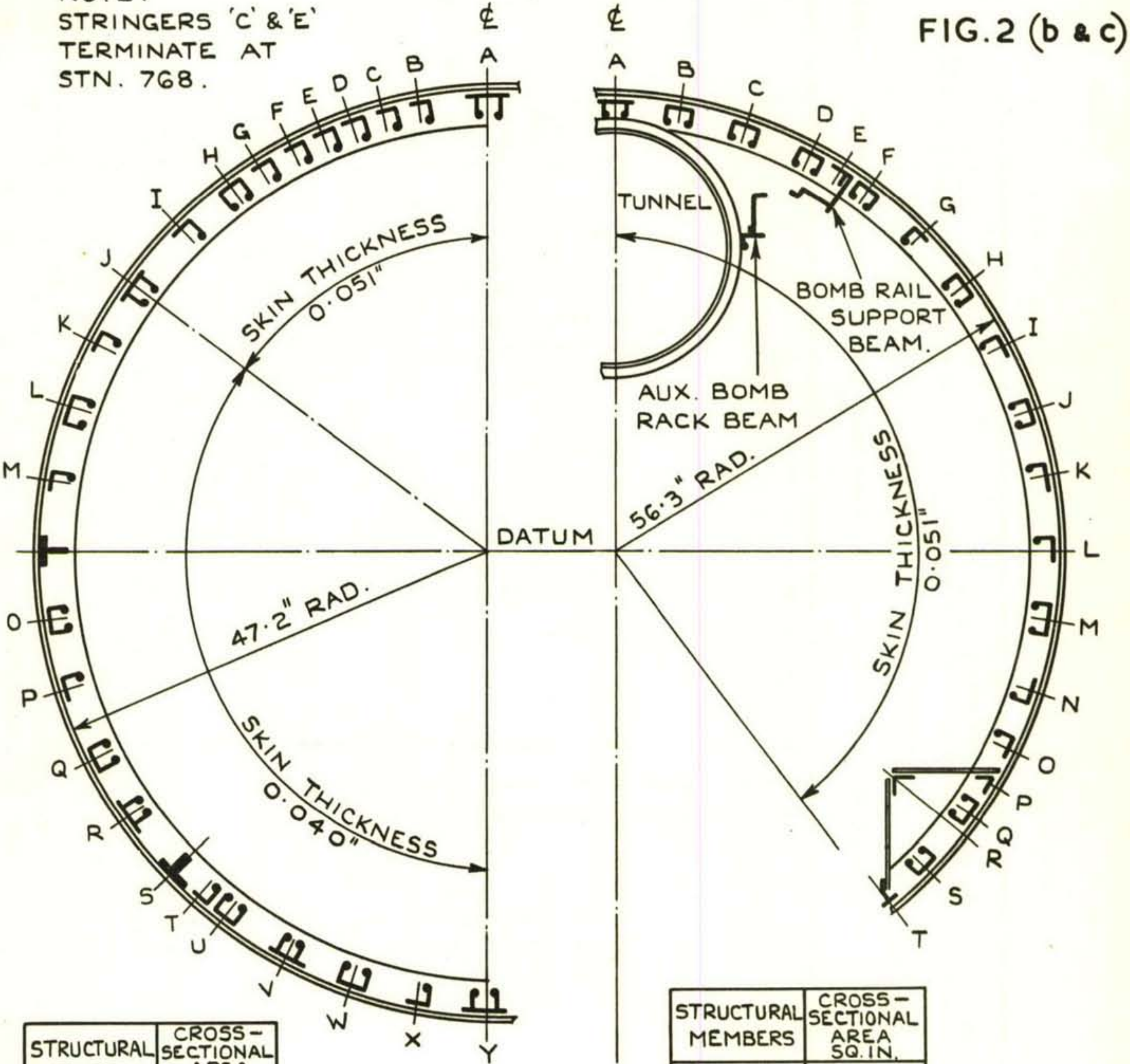
NOTE: CROSS-SECTIONAL AREAS REFER TO HALF TARGET ONLY

STN. 300
(FORWARD BOMB BAY)

FIG. 2(a) HALF-SECTION OF 'B 29' FUSELAGE AT ATTACK STATION.
(TARGET 3 B.)

FIG. 2 (b & c)

NOTE:
STRINGERS 'C' & 'E' TERMINATE AT STN. 768.



STRUCTURAL MEMBERS	CROSS-SECTIONAL AREA SQ. IN.
S	1·478
A.J.R.V.Y.	0·402
Q.U.W.H.	0·395
L.O.	0·301
N.	0·279
D.F.B.M.P.T.X.	0·173
C.E.G.I.K.	0·122
SKIN (0·051")	2·26
SKIN (0·040")	4·16

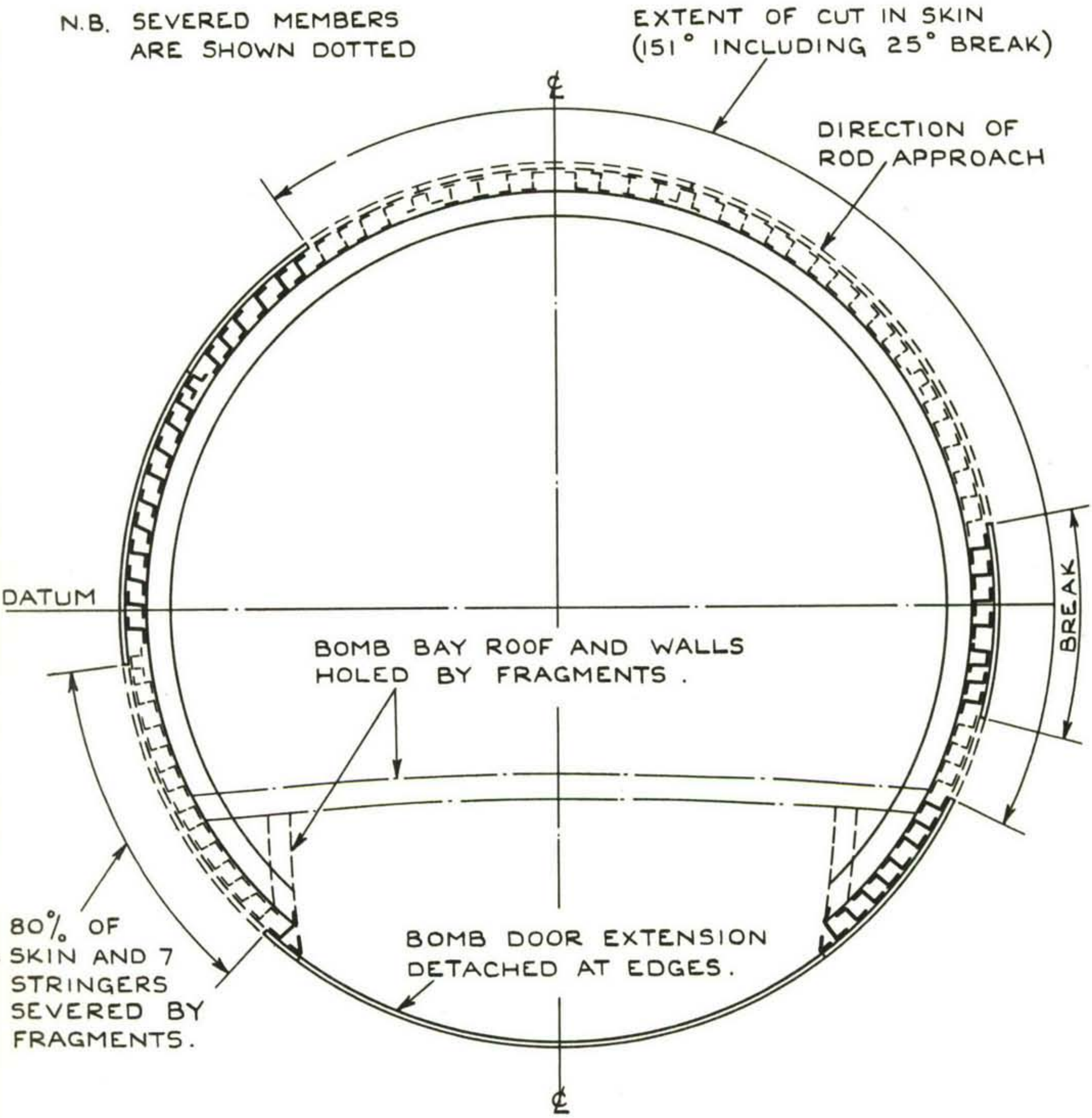
NOTE :-
CROSS-SECTIONAL AREAS REFER TO HALF TARGET ONLY.

STRUCTURAL MEMBERS	CROSS-SECTIONAL AREA SQ. IN.
R	0·940
T	2·534
P	0·732
A	0·402
B.F.Q.S.C.	0·395
H.J.M.	0·301
D.	0·198
K.L.N.O.	0·173
E.G.I.	0·122
SKIN (0·051")	7·14

2(b) STN. 768.
(MID CREW COMPARTMENT)
(TARGETS 3A, 4A, & 5A).

2(c) STN. 566.
(AFT BOMB BAY)
(TARGET 2).

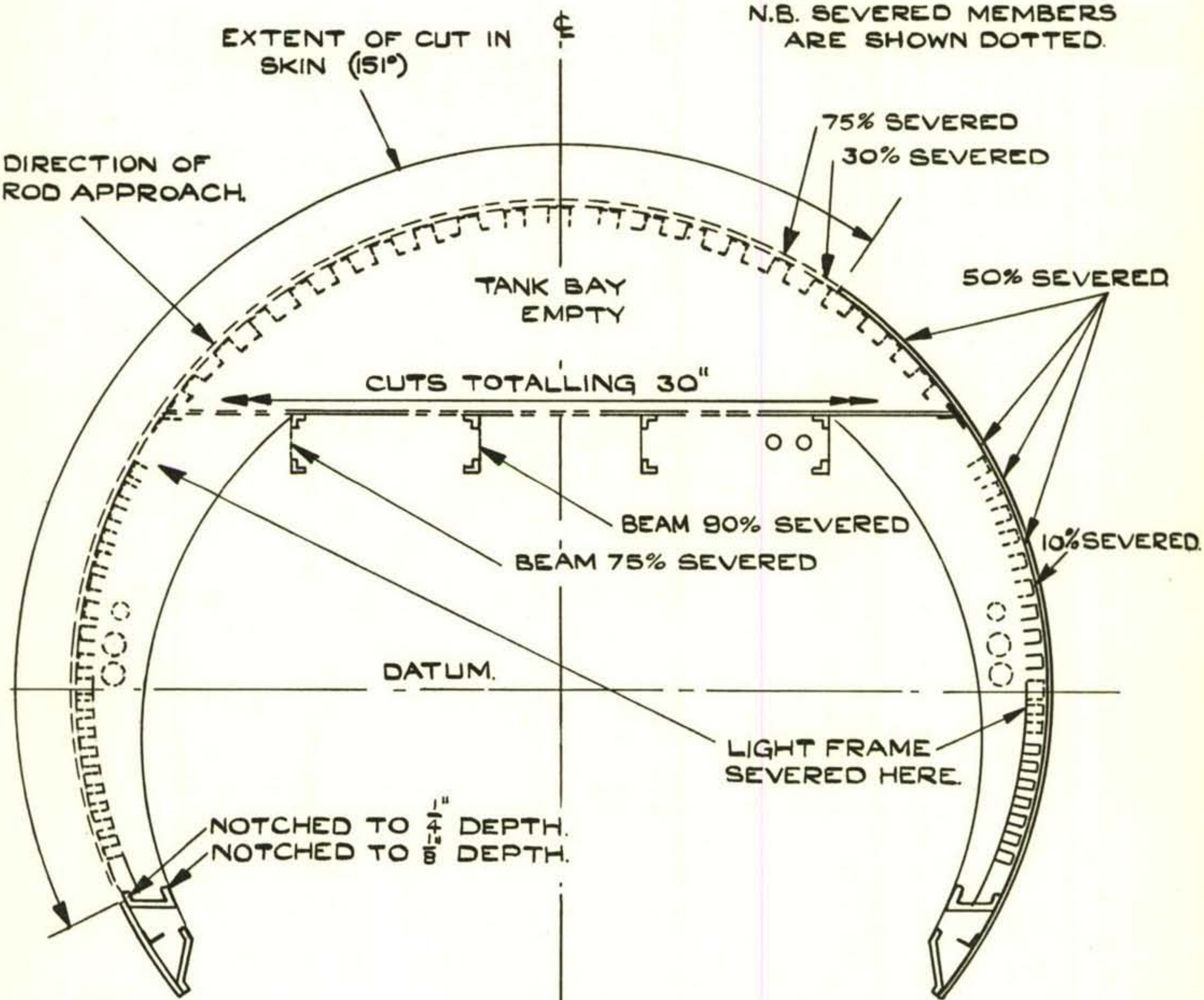
FIG. 2. (b & c) HALF-SECTIONS OF 'B.29' FUSELAGES AT ATTACK STATIONS.



RESULT: FUSELAGE SECTION ATTACKED IN THE '1g' LOADED CONDITION. FAILED ON ATTACK.

STN. 963 OF LOADED 'VALIANT 673' FUSELAGE

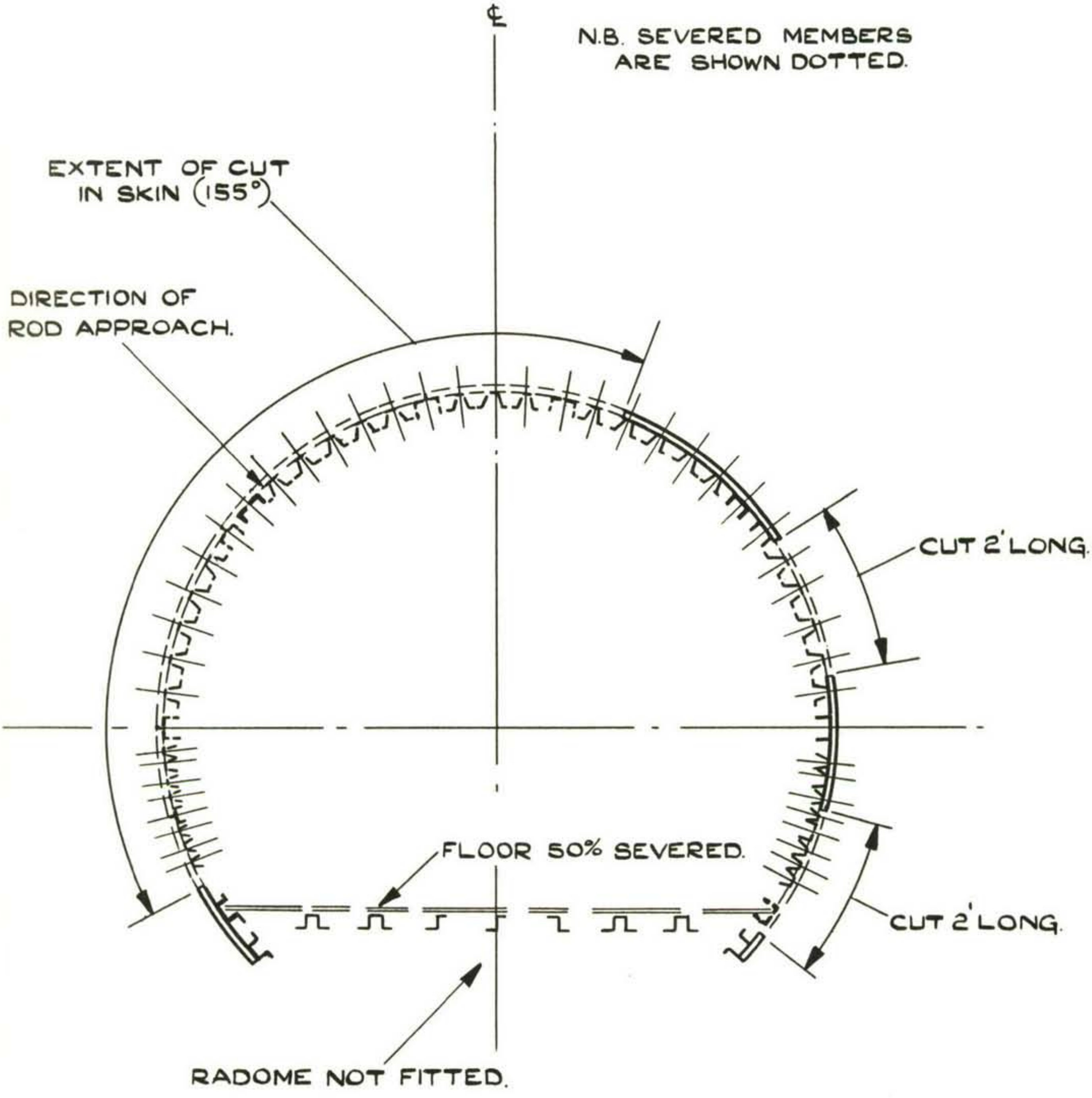
FIG. 3. TARGET 1A. RECORD OF ROD DAMAGE TO 'VALIANT TYPE 673' FUSELAGE. (1/4 IN. ROD. LOW VEL.)



RESULT : FUSELAGE SECTION ATTACKED IN THE UNLOADED CONDITION. FUSELAGE FAILED UNDER SUBSEQUENT APPLICATION OF LOAD. EQUIVALENT TO 0·94g.

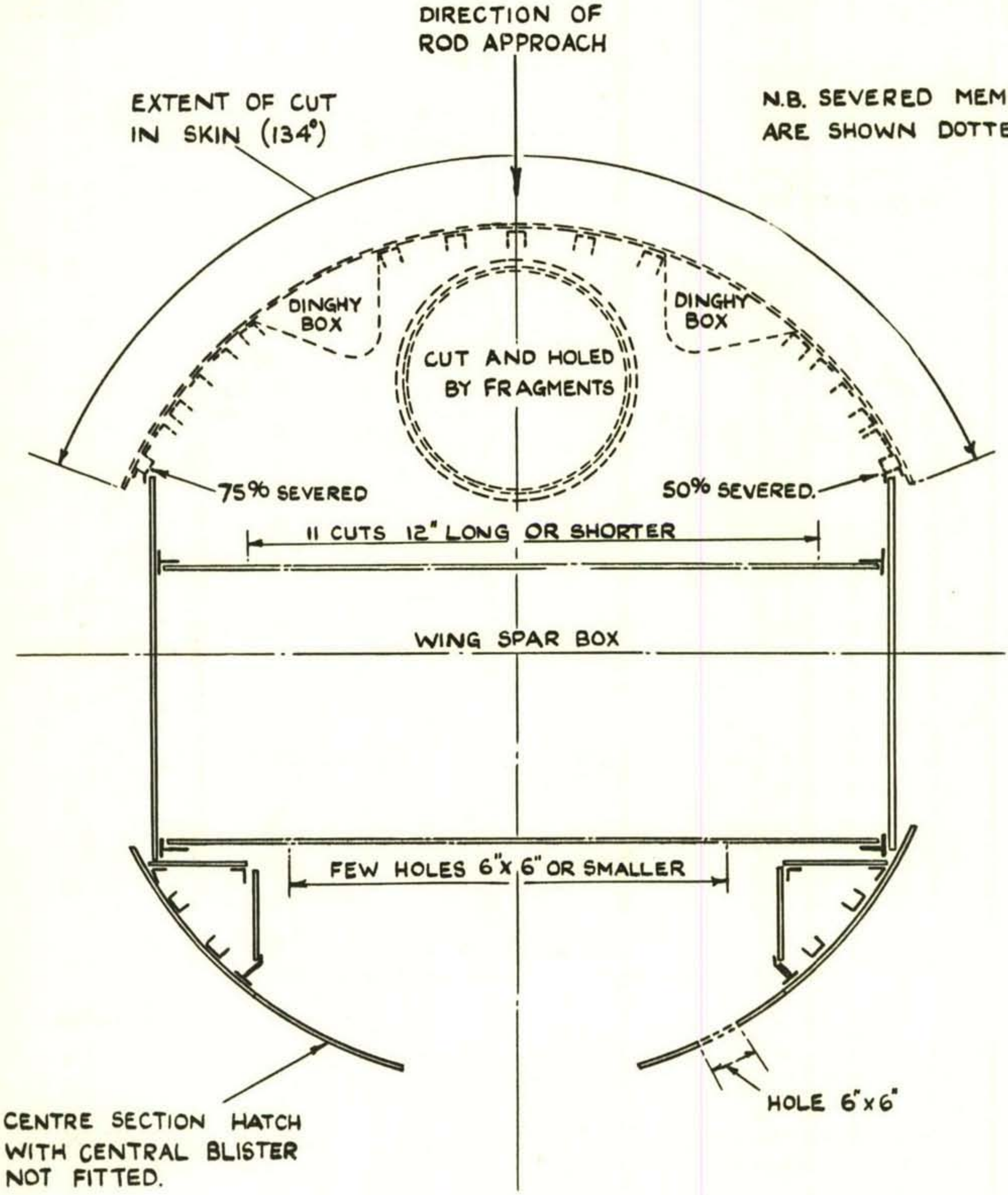
STN. 740 OF LOADED 'VICTOR' FUSELAGE.

FIG. 4. TARGET 1 B. RECORD OF ROD DAMAGE TO 'VICTOR' FUSELAGE (1/4 IN. ROD. LOW VEL.)



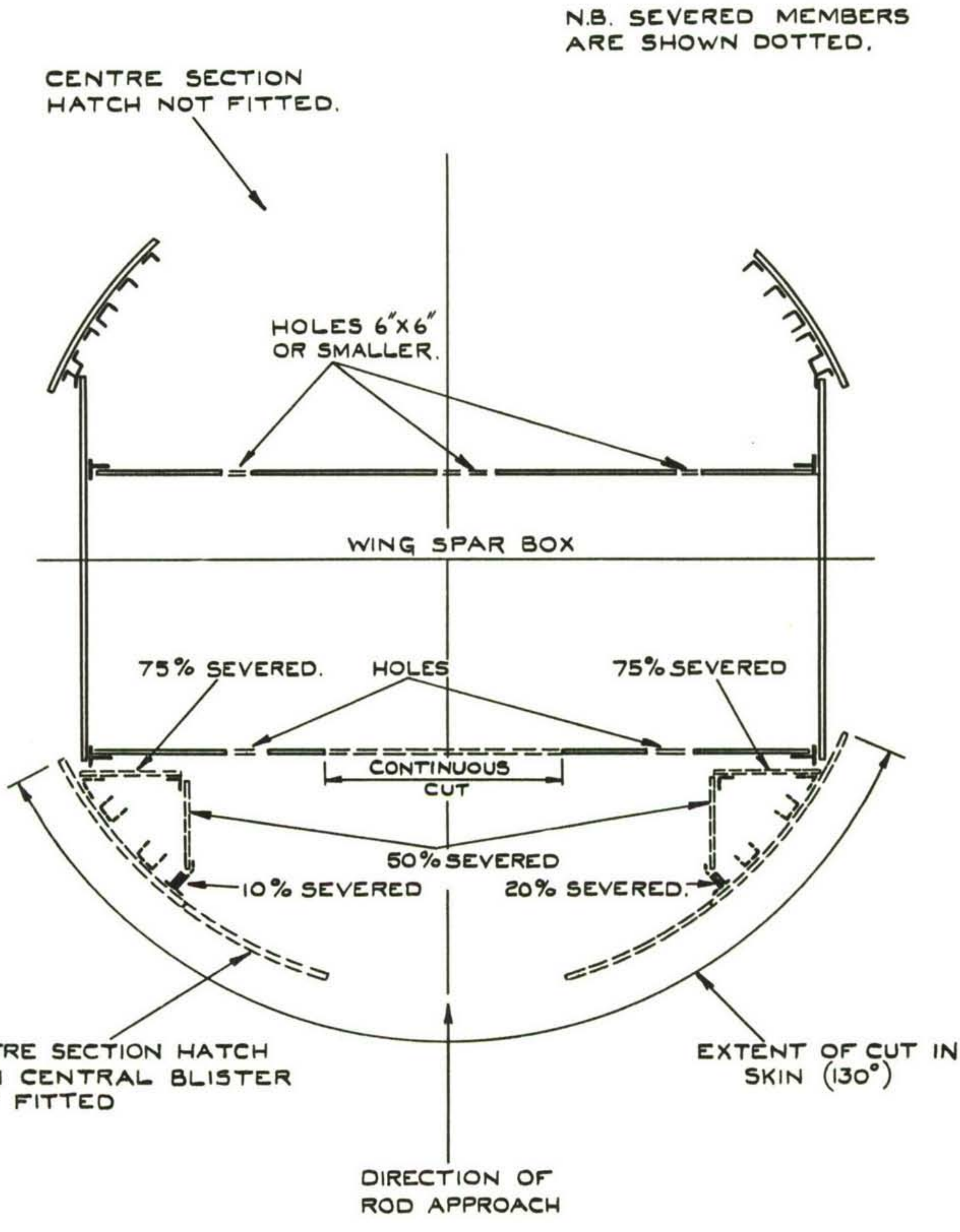
STN. 940 OF UNLOADED 'VICTOR' FUSELAGE.

FIG. 5. TARGET 6. RECORD OF ROD DAMAGE TO 'VICTOR' PROTOTYPE TARGET (1/4 IN. ROD. LOW VEL.)



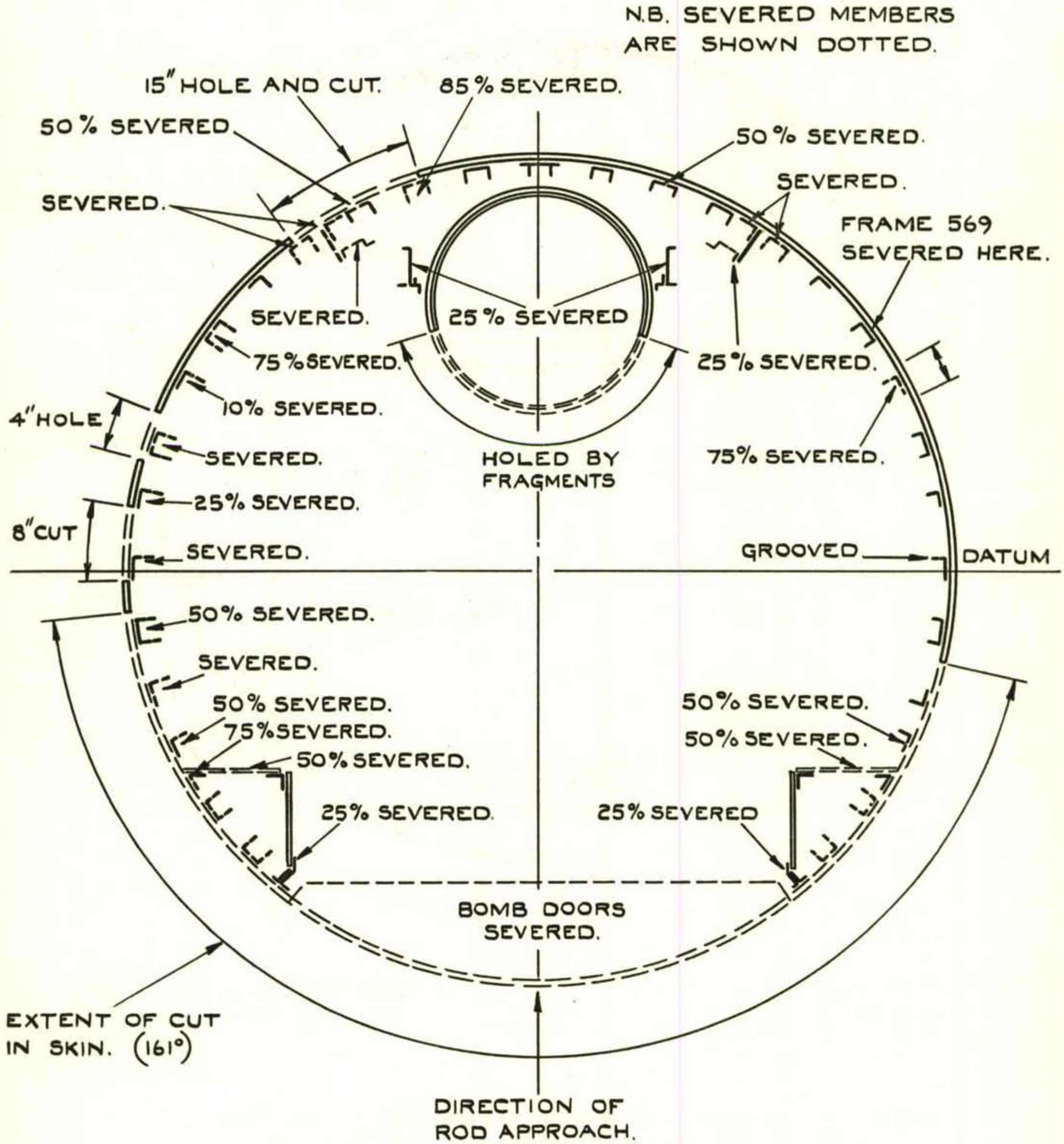
STN. 434 OF UNLOADED B 29 FUSELAGE.

FIG. 6. TARGET 7A. RECORD OF ROD DAMAGE TO 'B29' TARGET (1/4 IN. ROD. LOW VEL.)



STN. 434 OF UNLOADED B. 29 FUSELAGE.

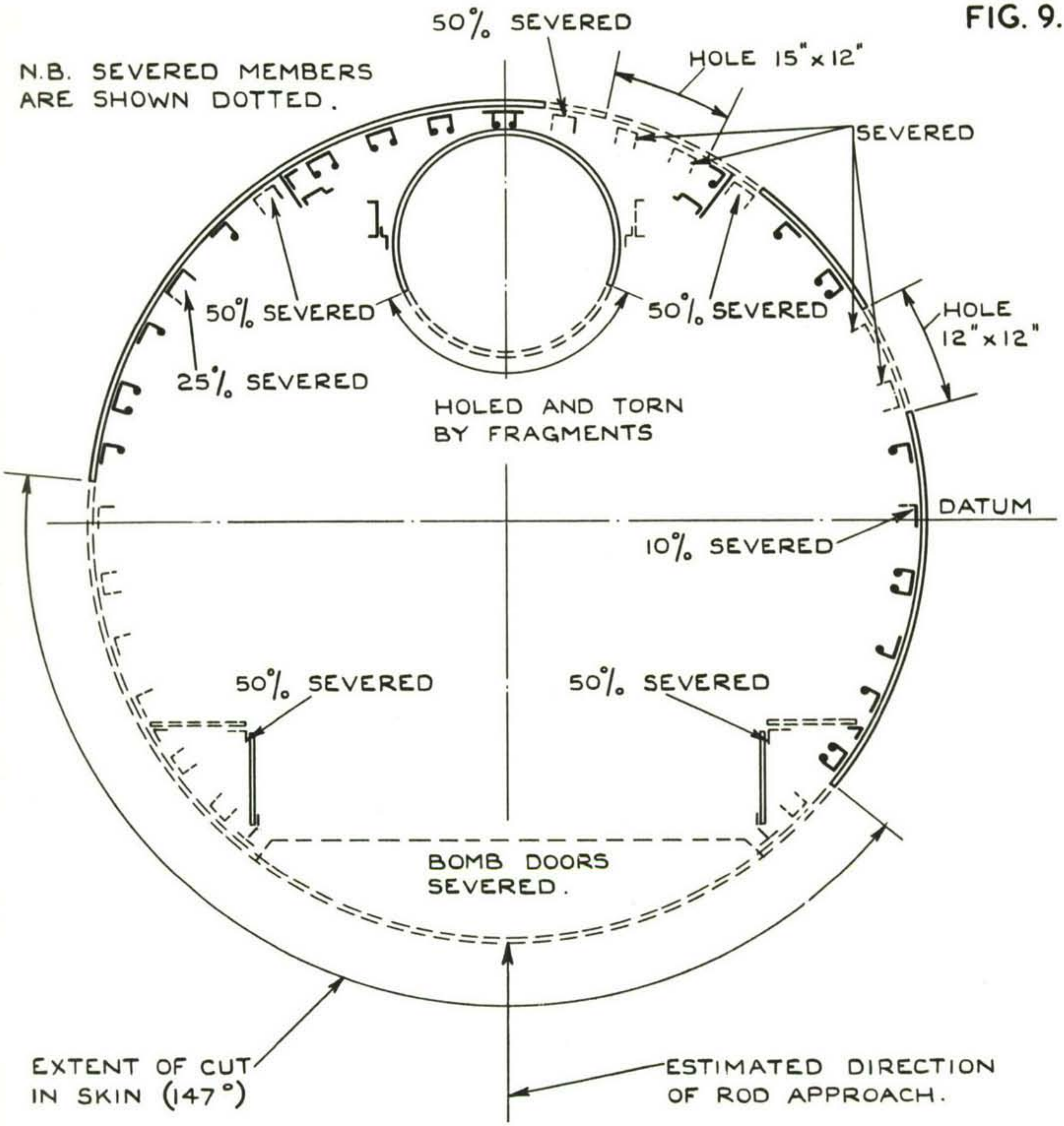
FIG. 7. TARGET 7 B. RECORD OF ROD DAMAGE TO 'B.29' TARGET ($\frac{1}{4}$ IN. ROD. LOW VEL.)



RESULT: FUSELAGE SECTION ATTACKED IN THE UNLOADED CONDITION, DID NOT FAIL UNDER SUBSEQUENT APPLICATION OF 11,160,000 LB. IN. BENDING MOMENT EQUIVALENT TO '2.3g' LOADING.

STN. 566 OF B.29 FUSELAGE.

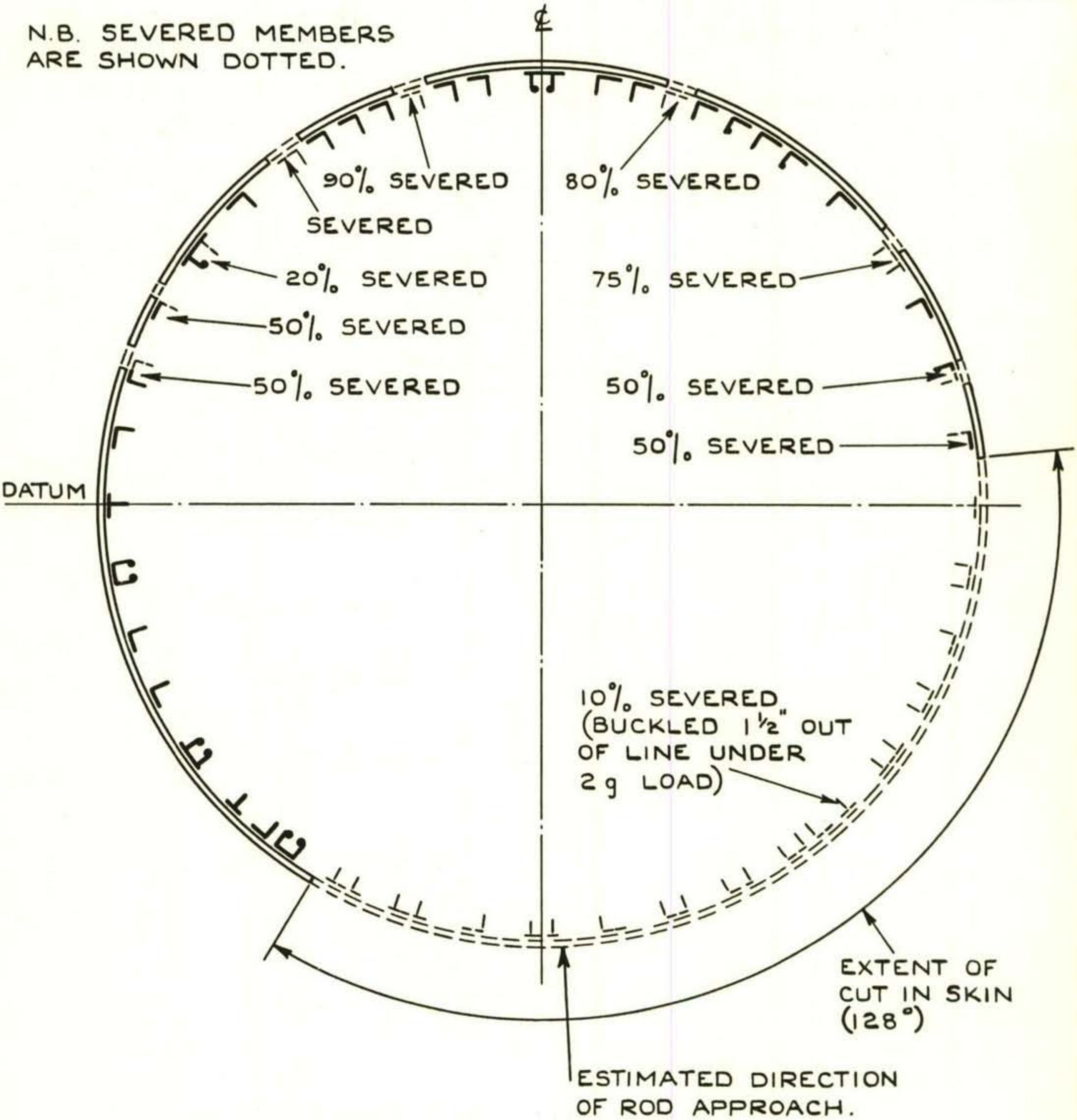
FIG. 8. TARGET 2. RECORD OF ROD DAMAGE TO 'B29' TARGET ($\frac{1}{4}$ IN. ROD. LOW VEL.)



RESULT :- FUSELAGE SECTION ATTACKED IN THE UNLOADED CONDITION. DID NOT FAIL UNDER SUBSEQUENT APPLICATION OF 6,175,700 LB. IN. BENDING MOMENT EQUIVALENT TO '2·8 g' LOADING.

STN. 300 OF 'B.29.' FUSELAGE.

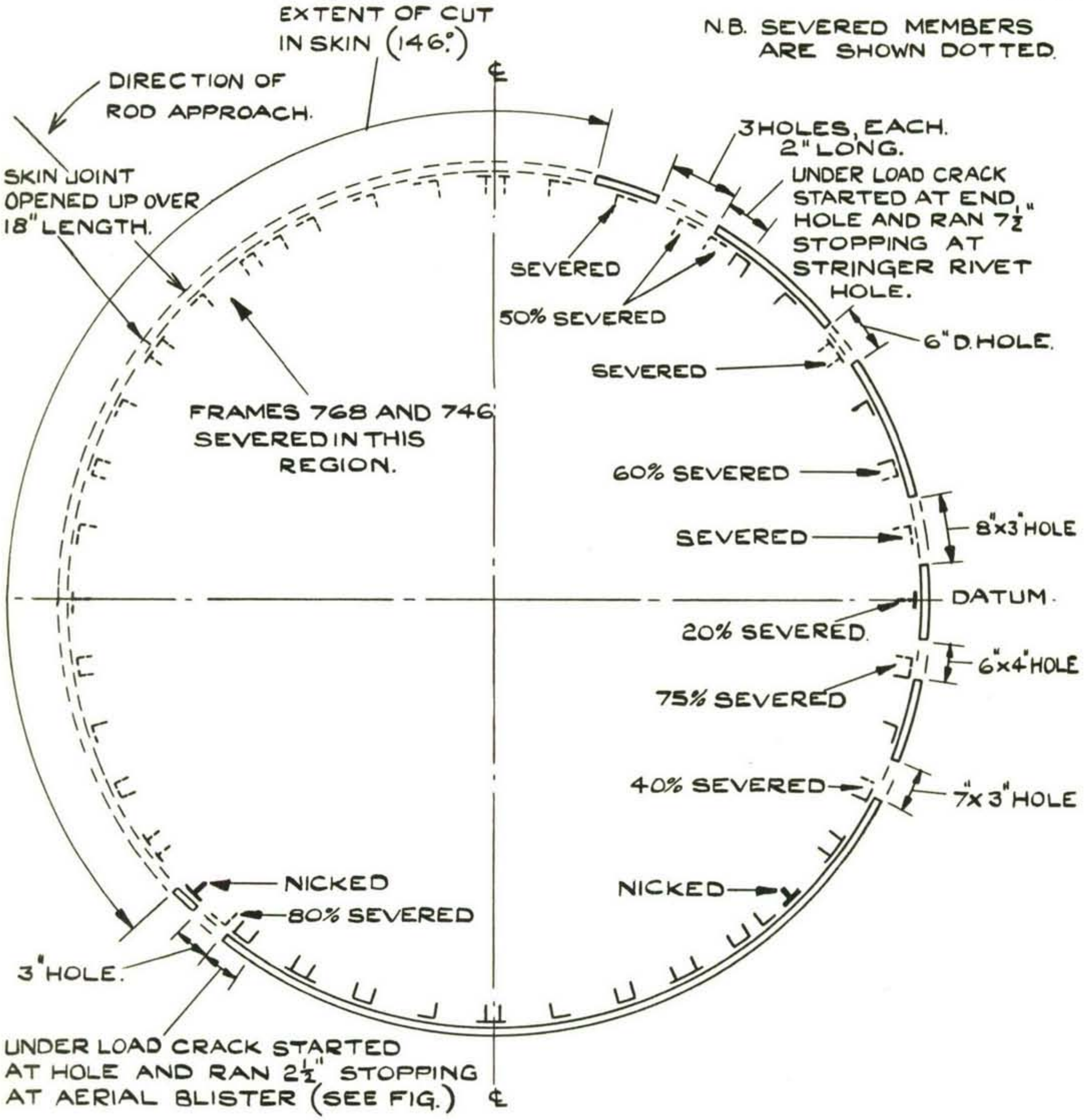
FIG. 9. TARGET 3B. RECORD OF ROD DAMAGE TO 'B.29' TARGET. (3/16 IN. ROD. HIGH VEL.)



RESULT :- FUSELAGE SECTION ATTACKED IN THE '1g' LOADED CONDITION. DID NOT FAIL AFTER APPLICATION OF 4,700,000 LB. IN. BENDING MOMENT EQUIVALENT TO '2g' LOADING.

STN. 768 OF 'B.29'. FUSELAGE.

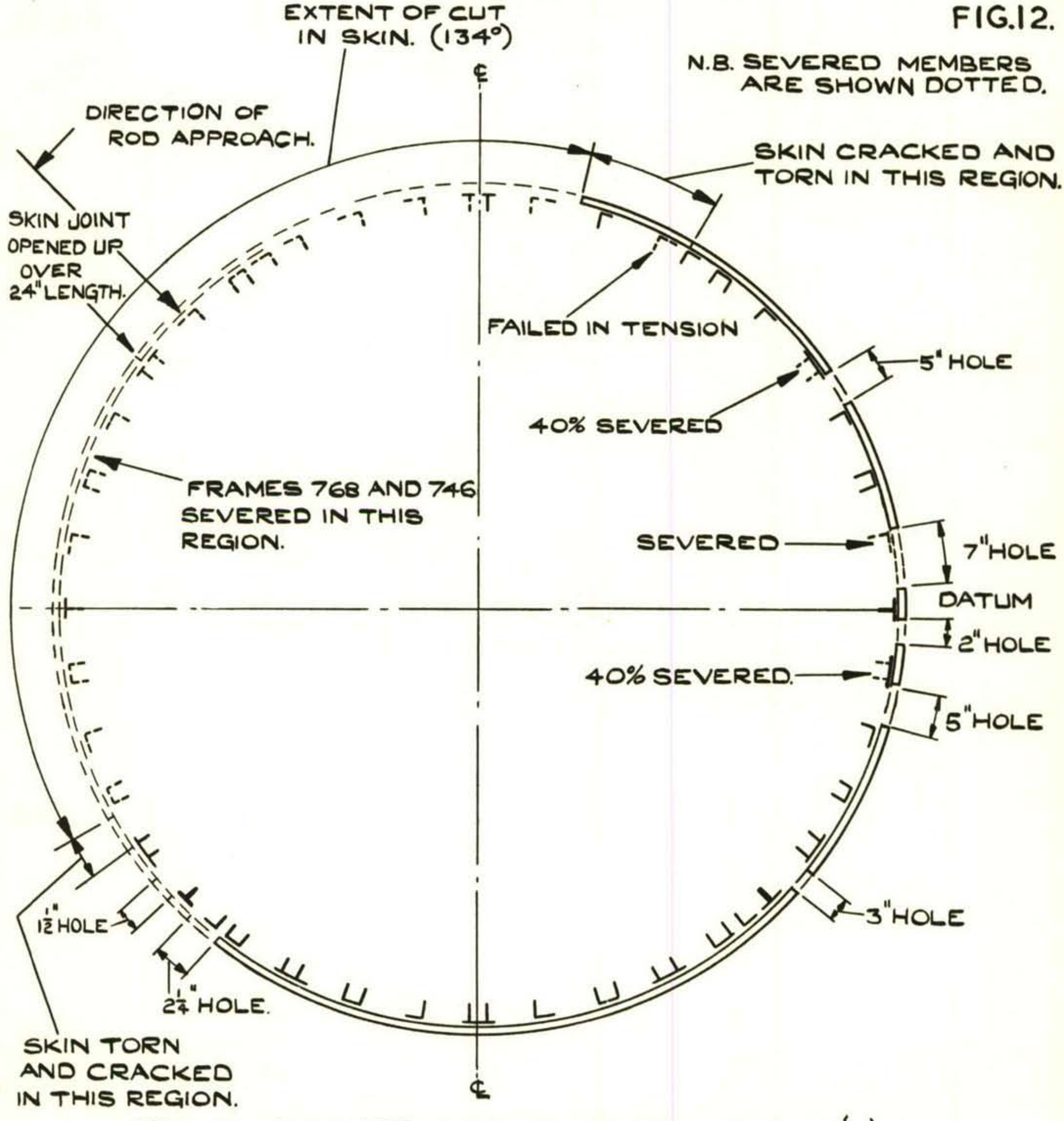
FIG. 10. TARGET 3A. RECORD OF ROD DAMAGE TO 'B.29'. TARGET. (3/16 IN. ROD. HIGH VEL.)



RESULT: FUSELAGE SECTION ATTACKED IN THE UNLOADED CONDITION. DID NOT FAIL UNDER SUBSEQUENT APPLICATION OF 4,980,000 LB.IN. BENDING MOMENT EQUIVALENT TO '2·1g' LOADING.

STN. 768 OF 'B.29' FUSELAGE
(NOTE STRINGERS 'C' & 'E' OF FIG. 28 NOT PRESENT IN THIS TARGET.)

FIG. 11. TARGET 4A. RECORD OF ROD DAMAGE TO 'B.29' TARGET. (3/16 IN. ROD. HIGH VEL.)



RESULT: FUSELAGE SECTION ATTACKED IN THE '1g' LOADED CONDITION DID NOT FAIL. FAILED AFTER APPLICATION OF 4,210,000 LB. IN. BENDING MOMENT, EQUIVALENT TO '1·8g' LOADING.

STN. 768 OF 'B 29' FUSELAGE.
(NOTE STRINGERS 'C' & 'E' OF FIG. 2B NOT PRESENT IN THIS TARGET.)

FIG. 12. TARGET 5 A. RECORD OF ROD DAMAGE TO 'B 29' TARGET. (3/16 IN. ROD. HIGH VEL.)

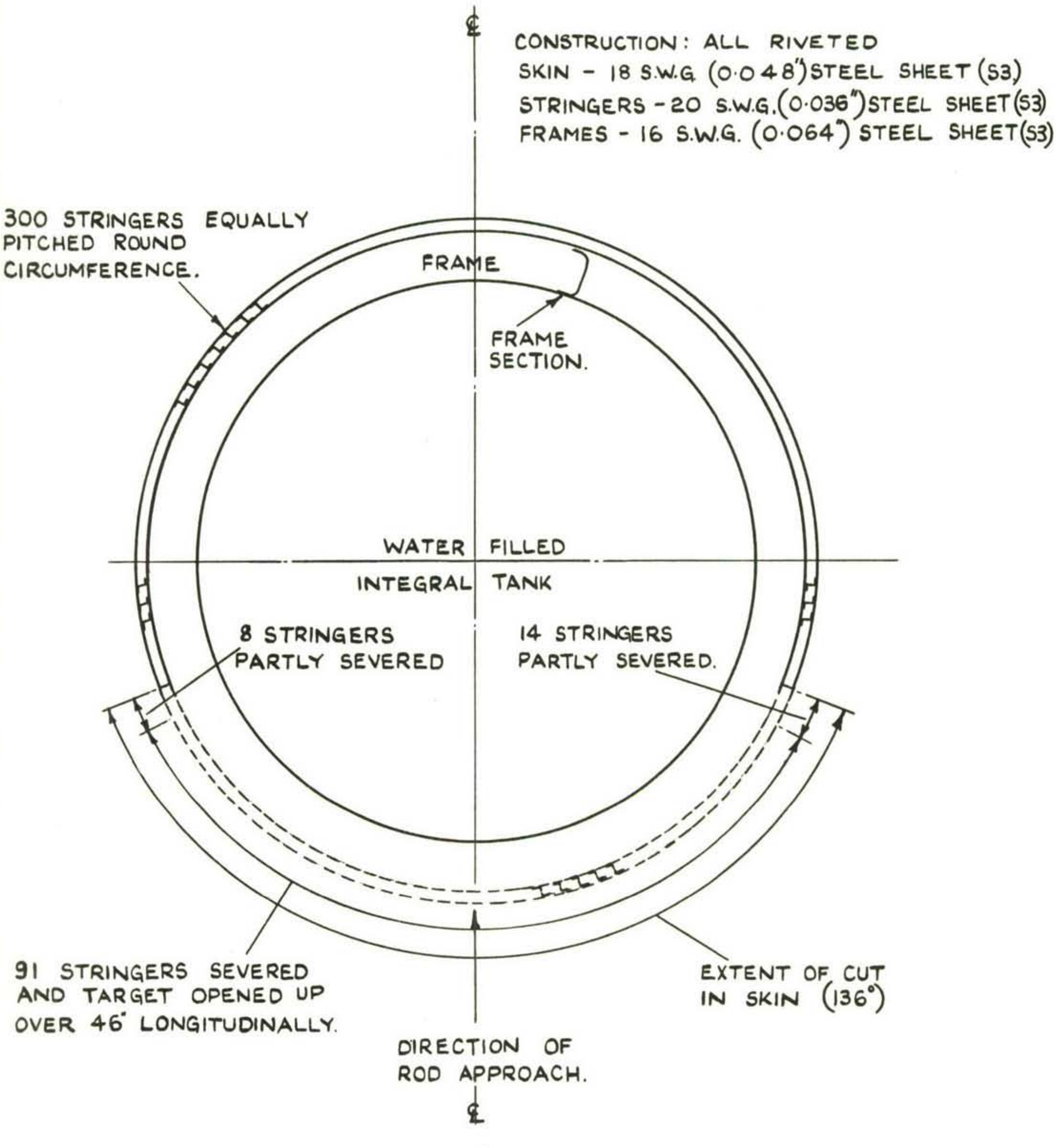
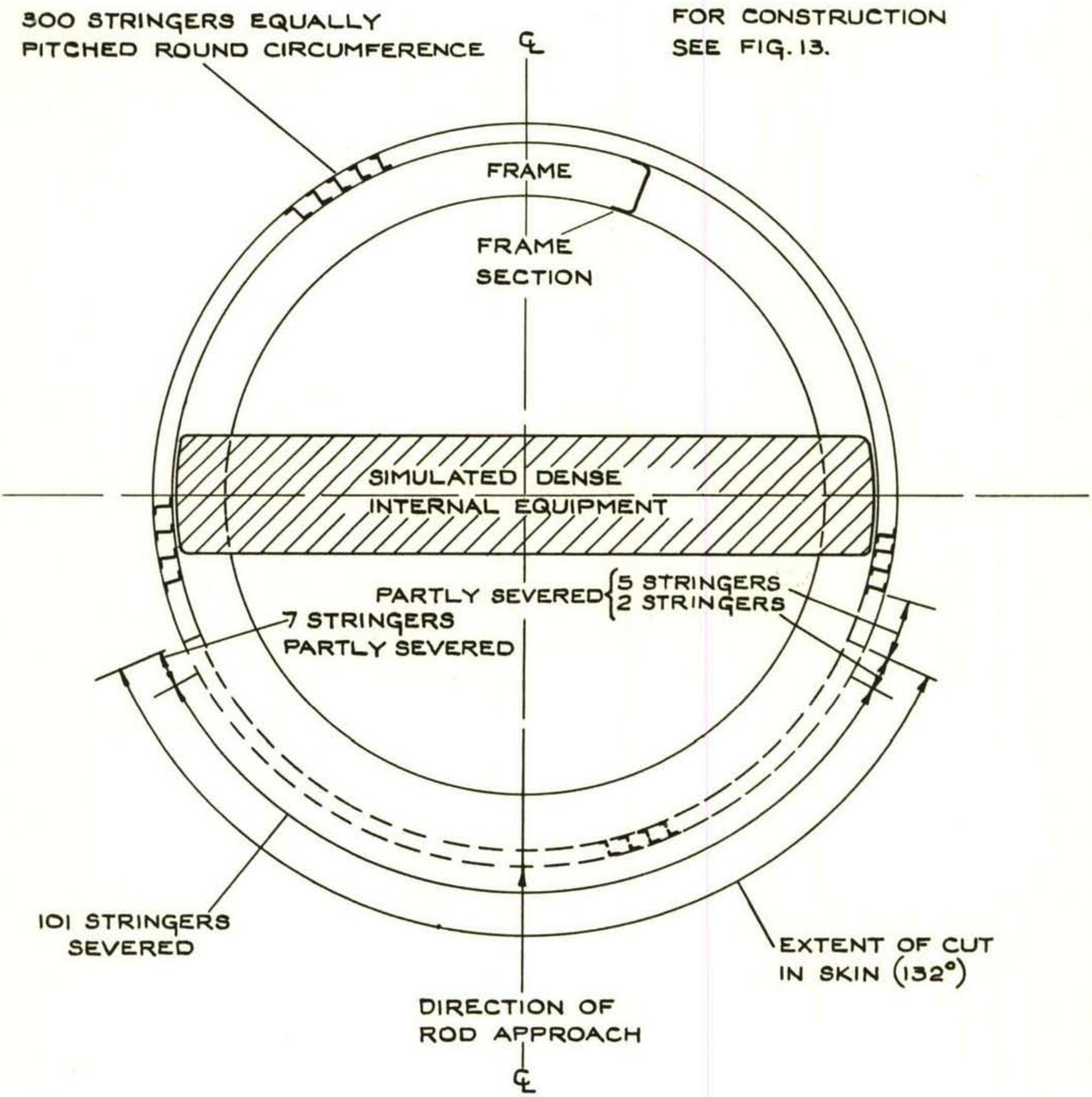


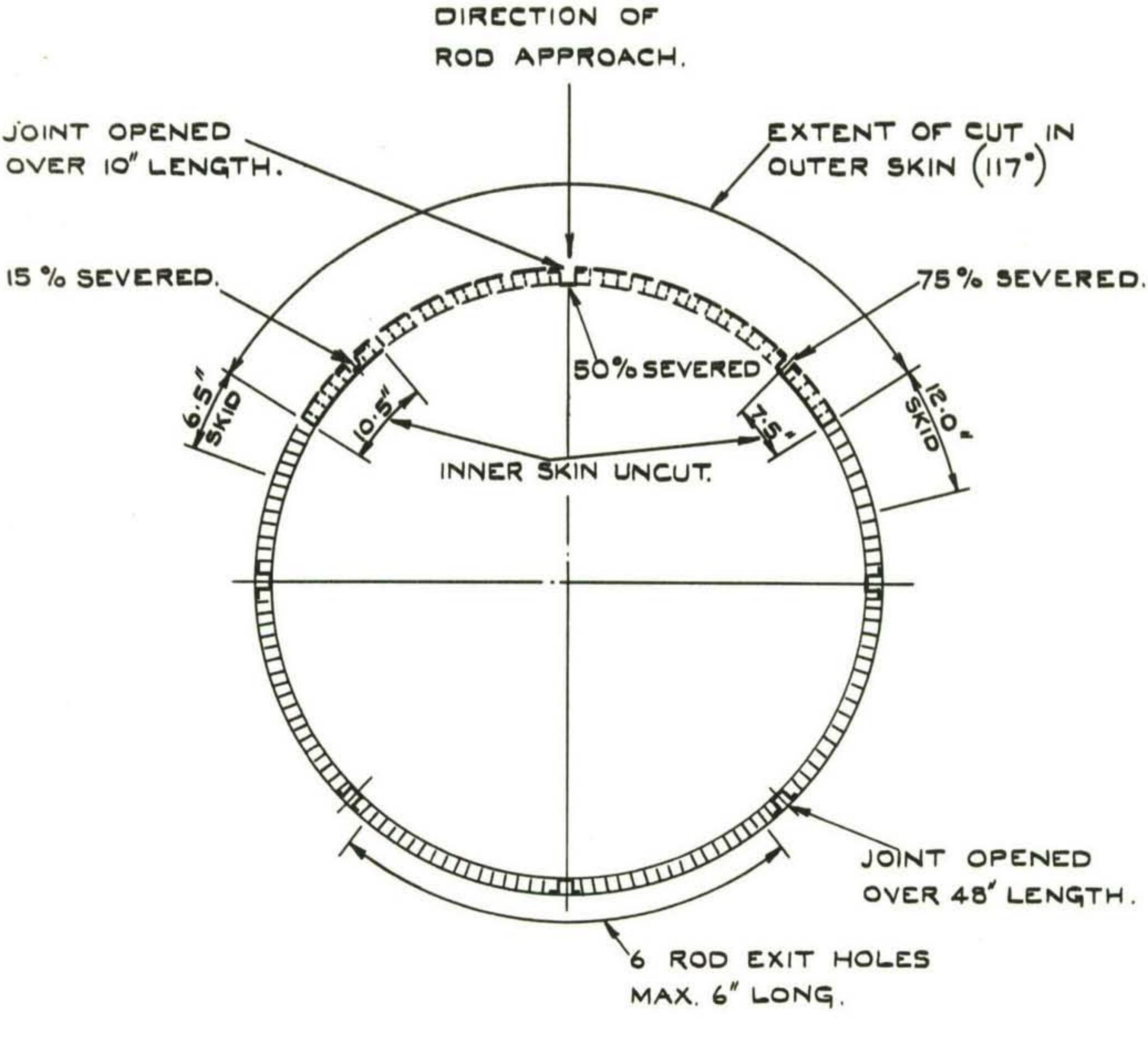
FIG. 13. TARGET 4B. RECORD OF ROD DAMAGE TO 'S.S.1'. REPLICA STEEL FUSELAGE SECTION. (3/16 IN. ROD. HIGH VEL.)



MID-LENGTH OF UNLOADED "S.S. 1" TARGET

FIG 14. TARGET 5 B. RECORD OF ROD DAMAGE TO "S.S. 1" REPLICA STEEL FUSELAGE SECTION. ($\frac{3}{16}$ IN. ROD. HIGH VEL.)

CONSTRUCTION: BRAZED HONEYCOMB SANDWICH.
SKINS - 18.S.W.G. STAINLESS STEEL (REX.448)
CORE - 0·003" MILD STEEL
JOINT STRINGERS - 16.S.W.G. D.T.D.171.



MID-LENGTH OF STEEL HONEYCOMB SANDWICH TARGET.

FIG.15. TARGET 8. RECORD OF ROD DAMAGE TO STEEL HONEYCOMB SANDWICH TARGET ($\frac{3}{16}$ IN. ROD. LOW VEL.)

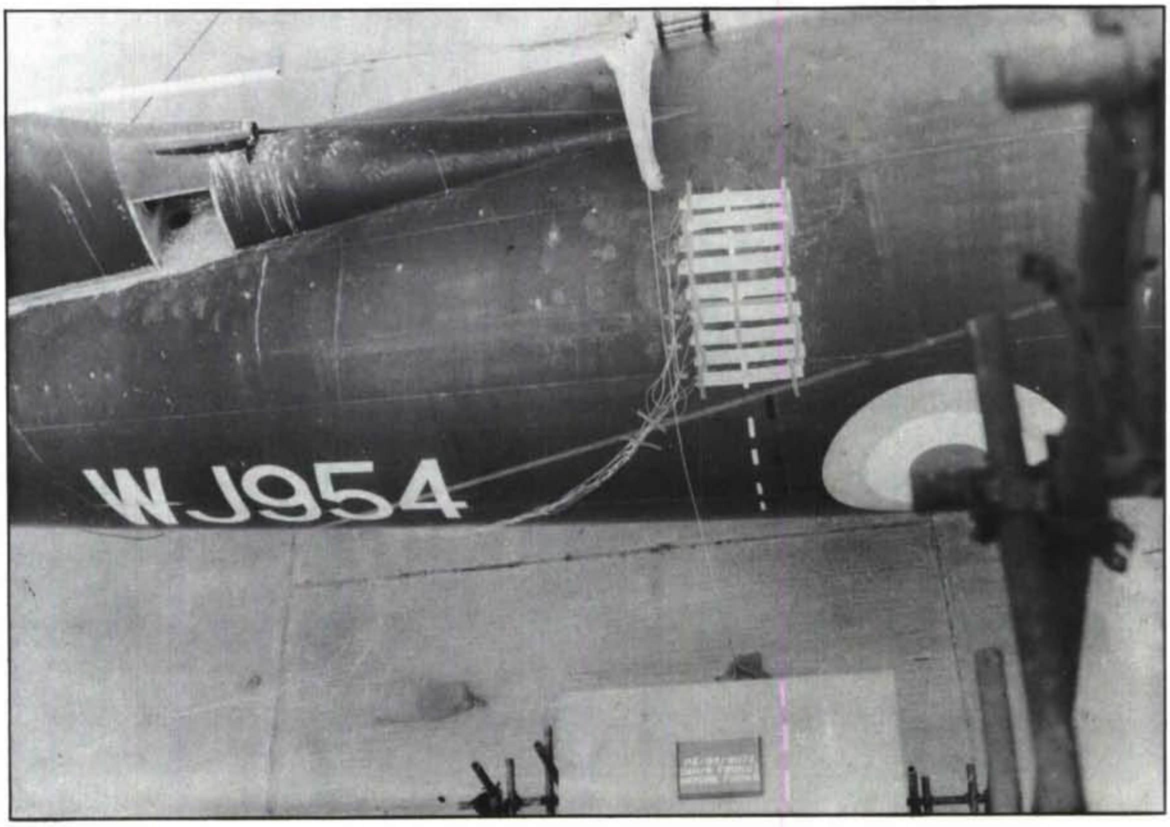


FIG.16a. TARGET 1a. LOADED VALIANT REAR FUSELAGE BEFORE ATTACK

FIG.16b. TARGET 1a. DAMAGE TO ROD "ENTRY" SIDE OF FUSELAGE SHOWING FAILURE

(LOW VEL. $\frac{1}{4}$in. ROD. STN. 963)

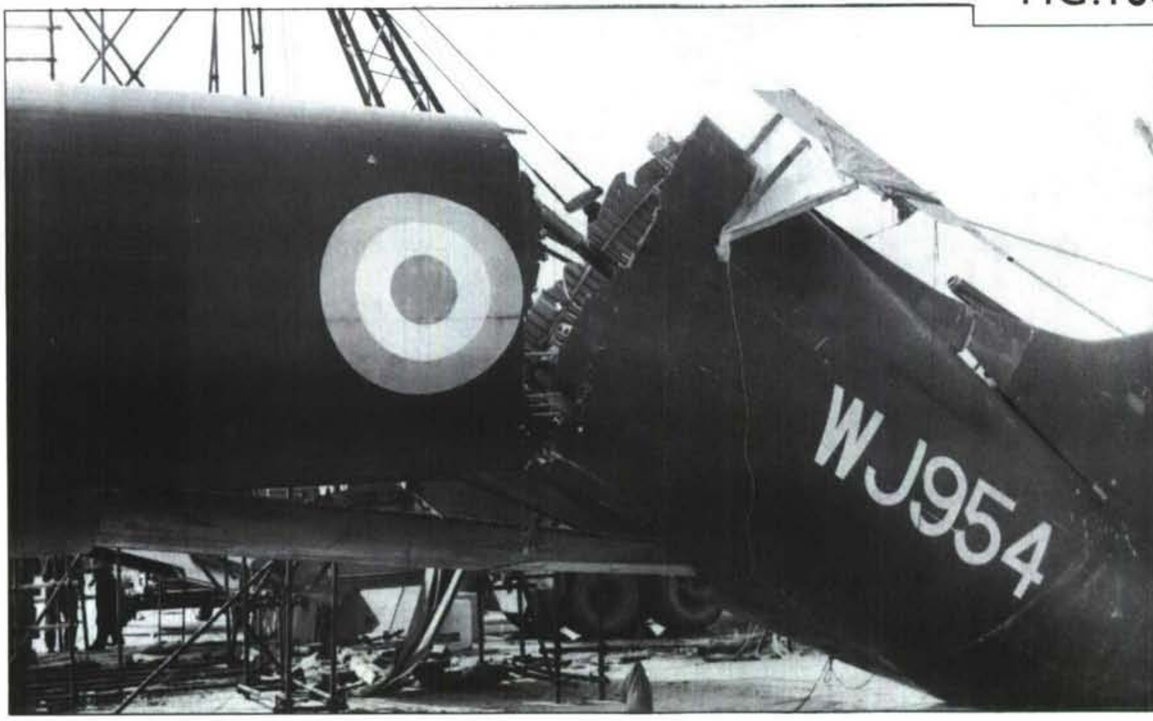


FIG. 16c. TARGET 1a. DAMAGE TO ROD "EXIT" SIDE OF "VALIANT" FUSELAGE (LOW VEL. $\frac{1}{4}$in. ROD. STN. 963)

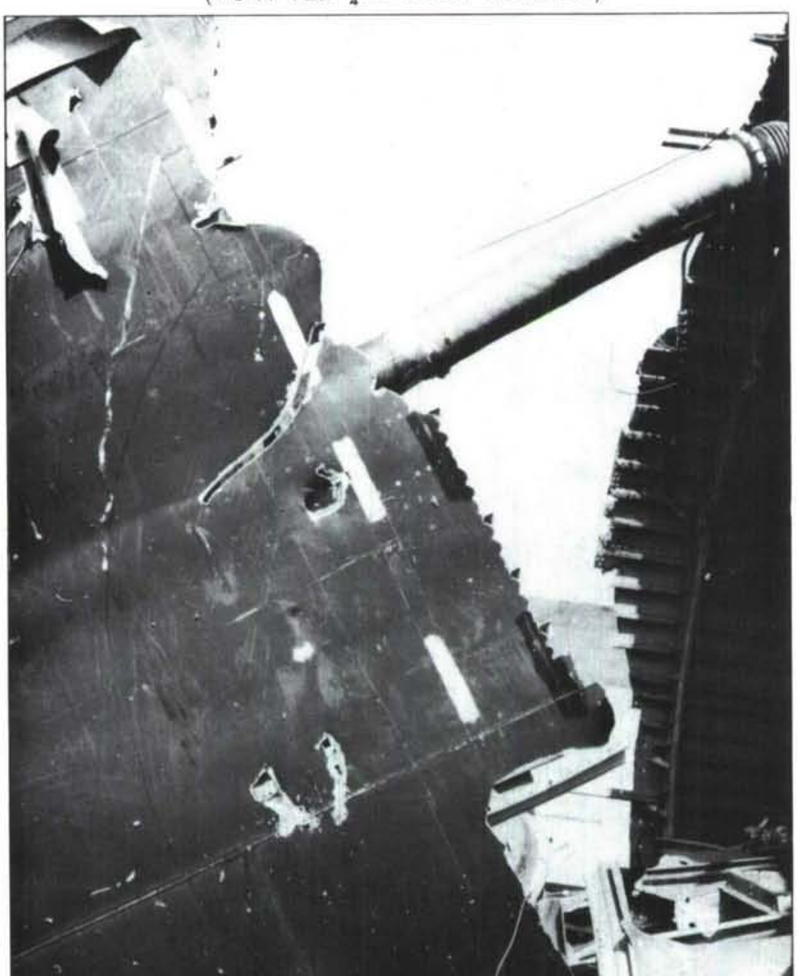


FIG. 16d. TARGET 1a. DETAIL OF FUSELAGE FAILURE AT STARBOARD SIDE END OF ROD CUT (LOW VEL. $\frac{1}{4}$in. ROD. STN. 963)

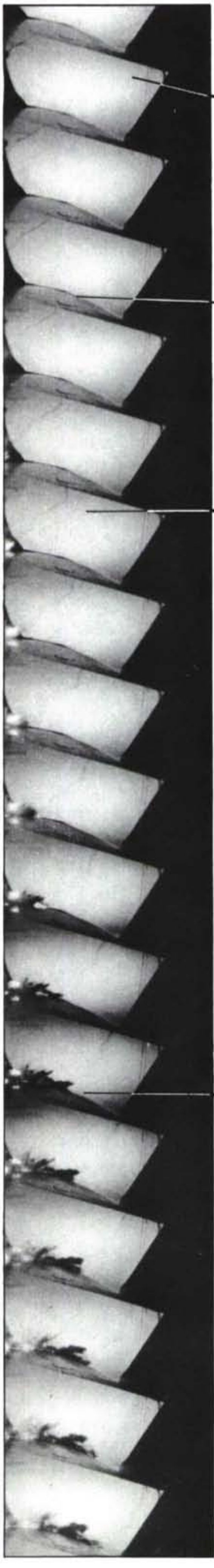


FIG. 16e. TARGET Ia. ROD BEHAVIOUR NEAR END OF CUT ON PORT SIDE OF "VALIANT" FUSELAGE (LOW VEL. $\frac{1}{4}$in. ROD. STN. 963)

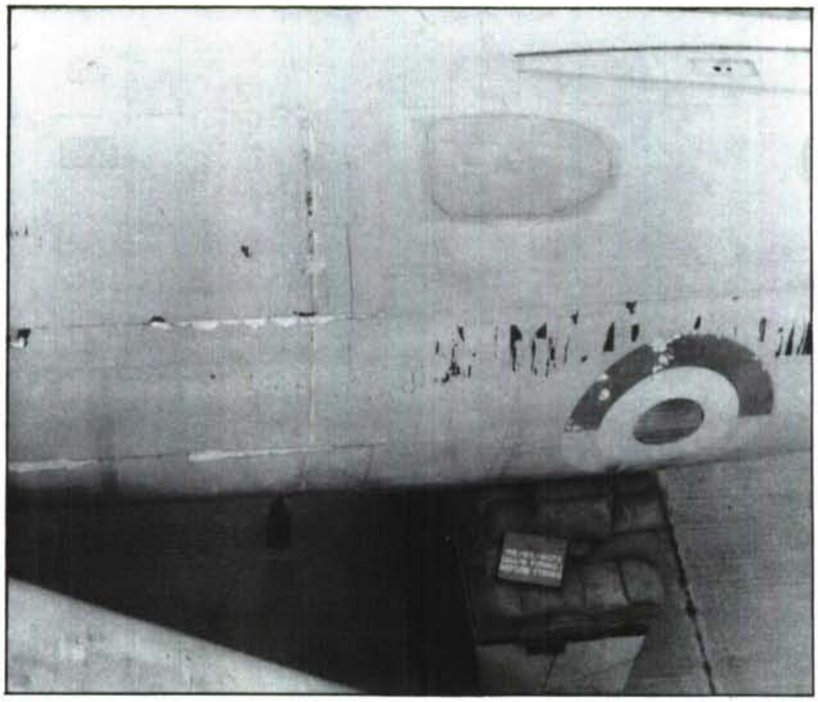


FIG. 17a. TARGET 1b. UNLOADED "VICTOR" FUSELAGE BEFORE ATTACK

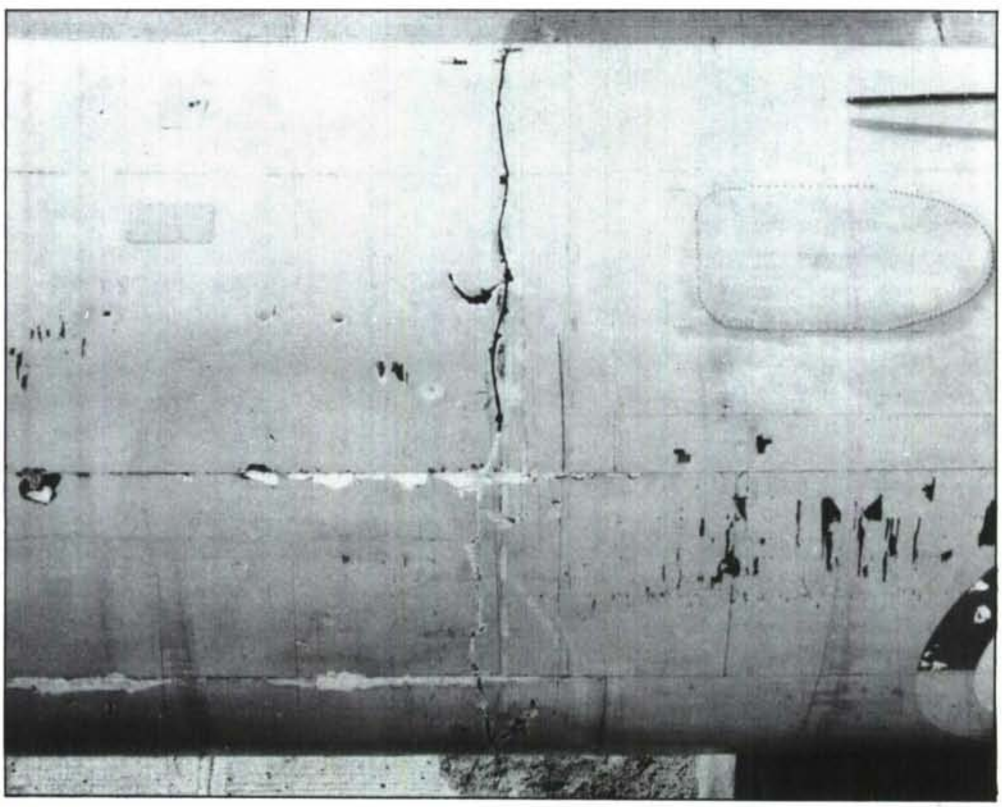


FIG. 17b. TARGET 1b. DAMAGE TO ROD "ENTRY" SIDE OF "VICTOR" FUSELAGE
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 740)

R.A.E. 164010 63

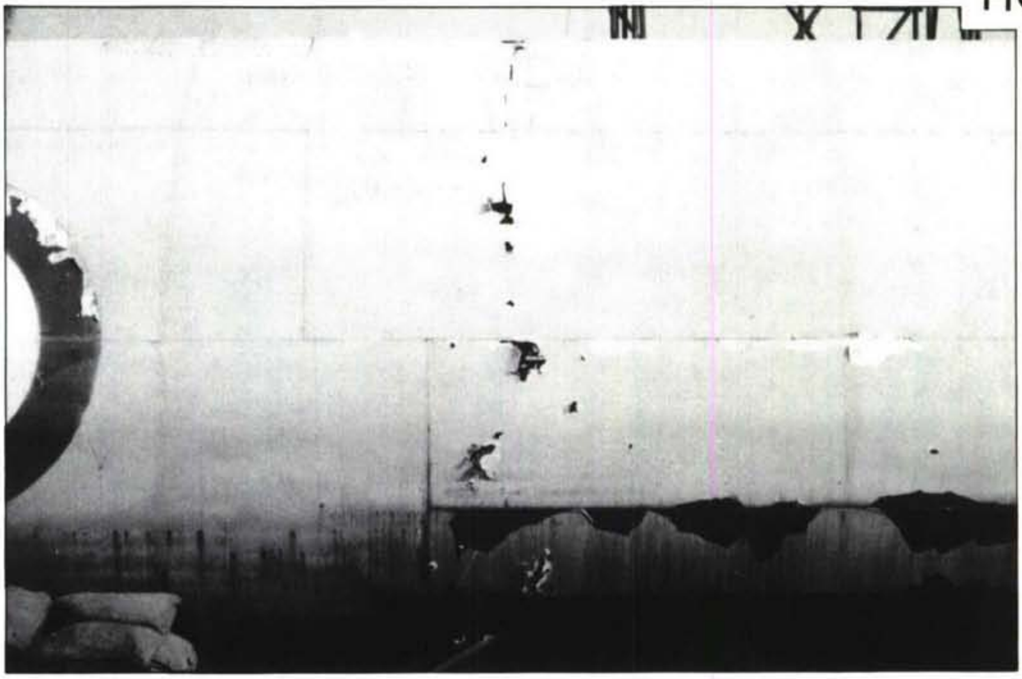


FIG. 17c. TARGET 1b. DAMAGE TO ROD "EXIT" SIDE OF "VICTOR" FUSELAGE
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 740)

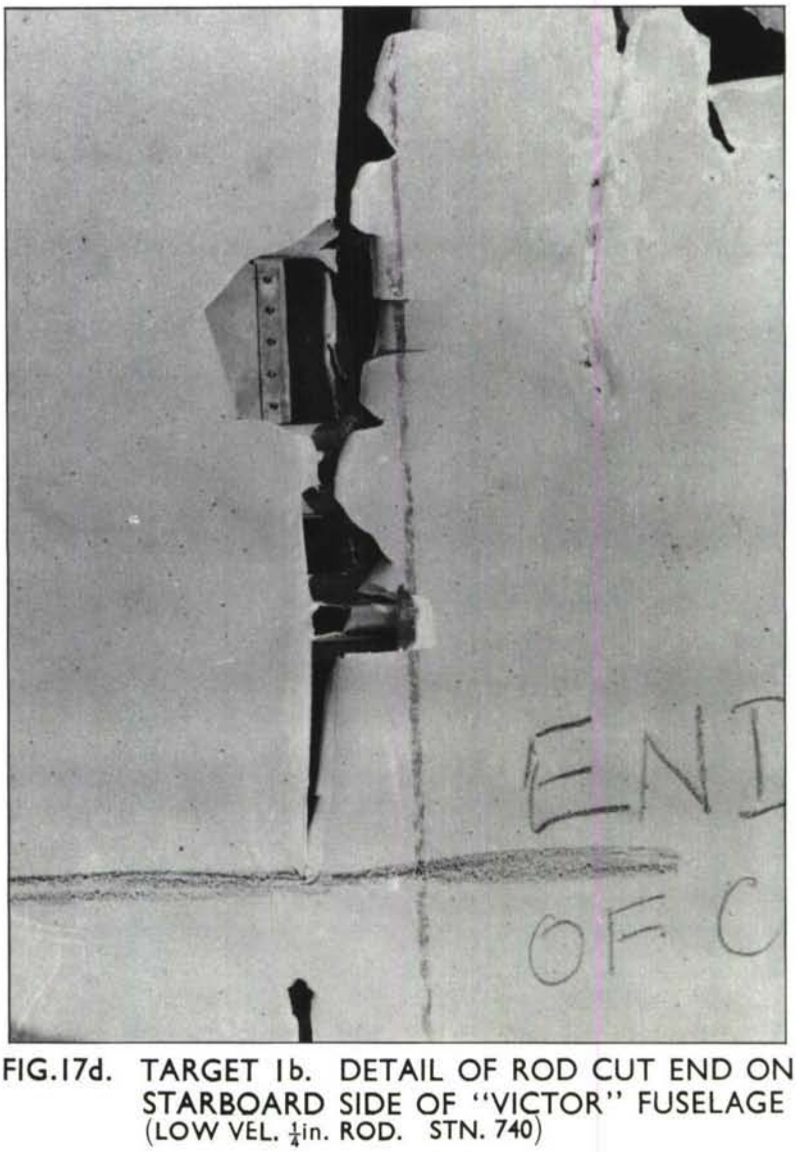


FIG. 17d. TARGET 1b. DETAIL OF ROD CUT END ON STARBOARD SIDE OF "VICTOR" FUSELAGE
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 740)

FIG. 17e. ROD "ENTRY" SIDE

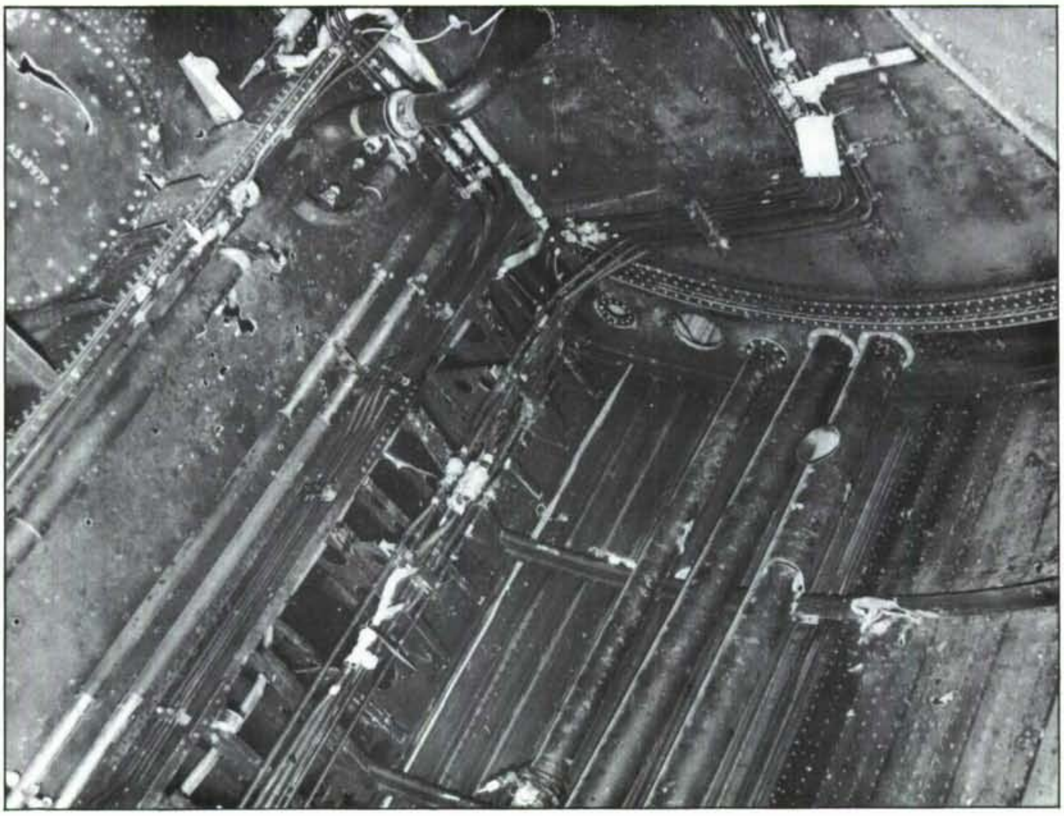


FIG. 17f. ROD "EXIT" SIDE

FIG. 17e AND f. TARGET Ib. ROD DAMAGE TO INTERIOR OF "VICTOR" FUSELAGE
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 740)

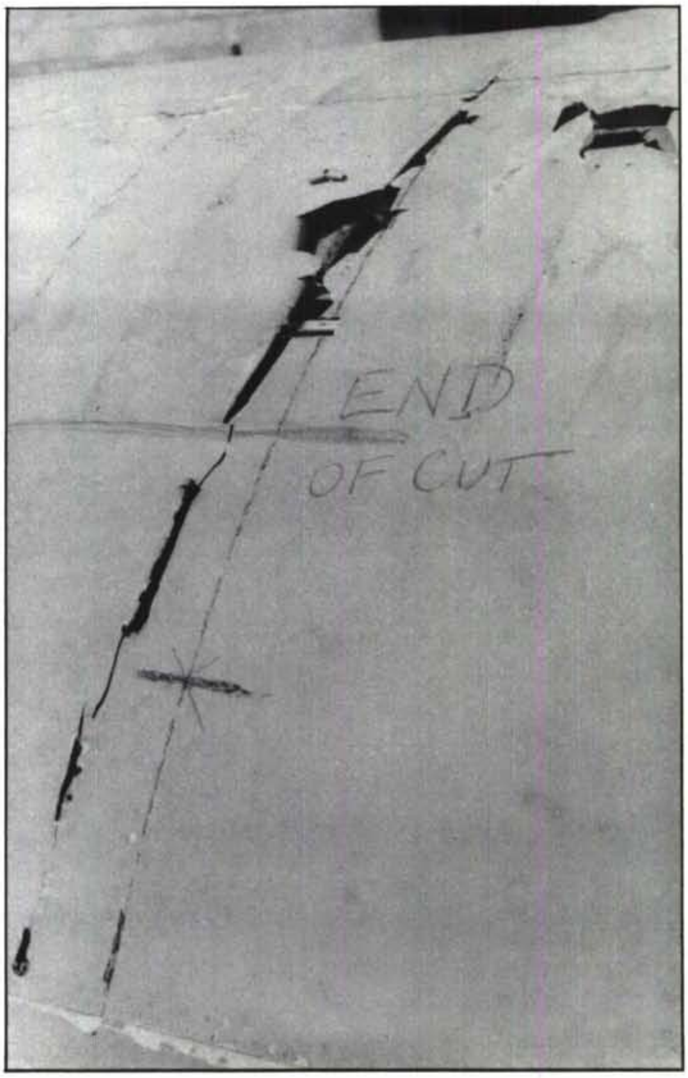


FIG.17g. TARGET 1b. ROD CUT END AFTER SUBSEQUENT LOADING EQUIVALENT TO 0·6 g.
COMPARE WITH FIG.17d.

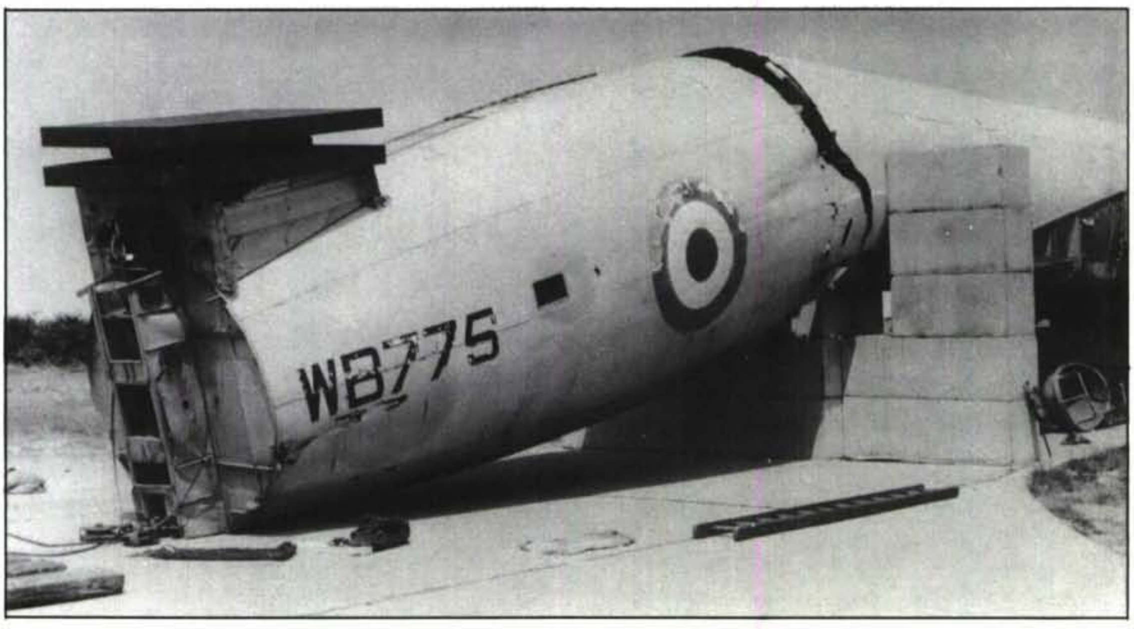


FIG.17h. TARGET 1b. FAILURE OF "VICTOR" FUSELAGE UNDER SUBSEQUENT LOADING EQUIVALENT TO 0·94 g.

FIG.17j. ROD "ENTRY" SIDE

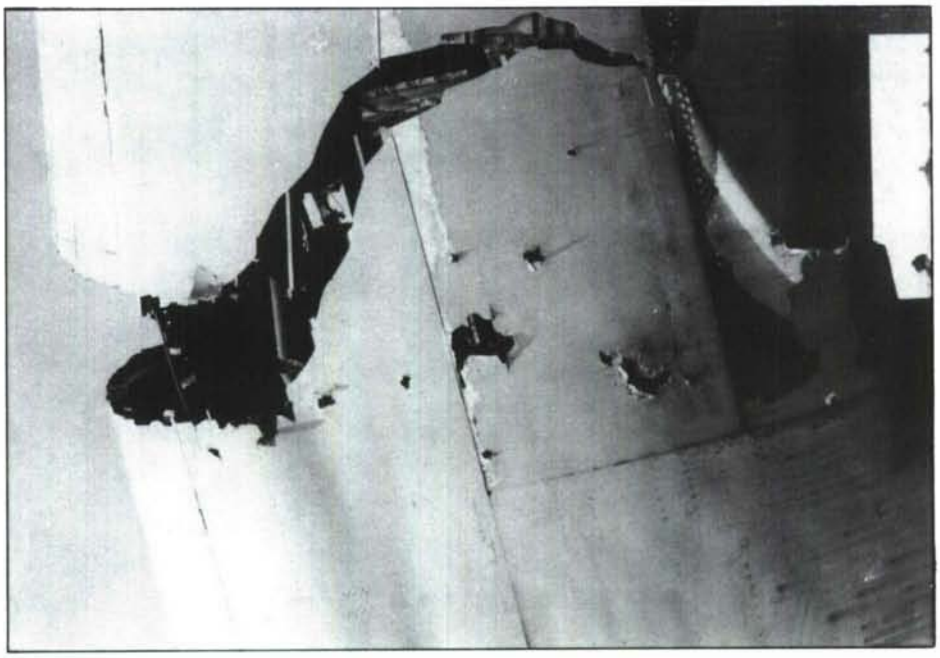


FIG.17k. ROD "EXIT" SIDE

FIG.17j AND k. TARGET 1b. "VICTOR" FUSELAGE AFTER FAILURE UNDER SUBSEQUENT LOADING EQUIVALENT TO 0·94 g.

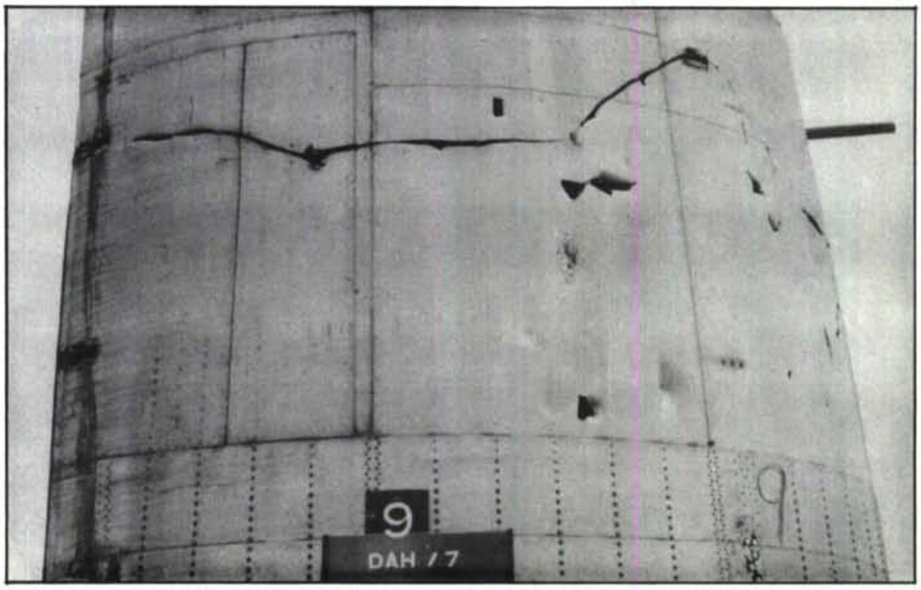


FIG. 18a. STARBOARD SIDE ROD "ENTRY" DAMAGE

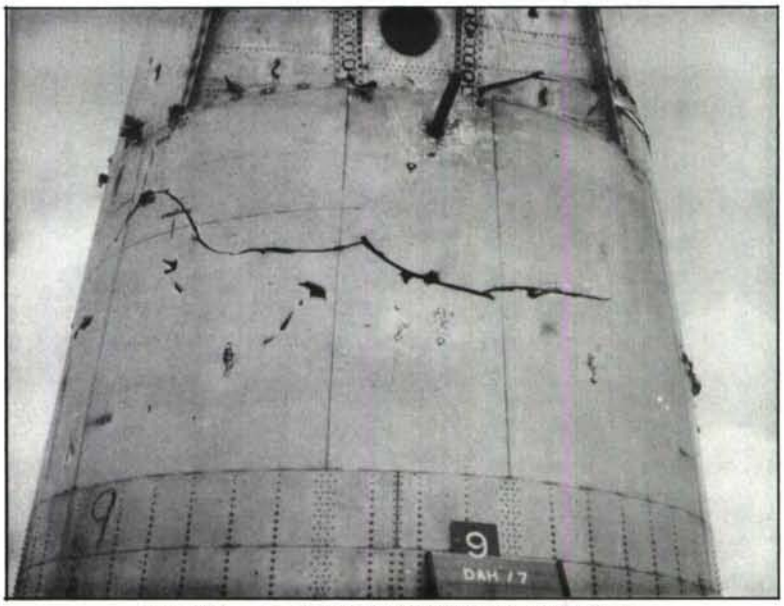


FIG. 18b. TOP ROD " ENTRY" DAMAGE

FIG. 18c. ROD "EXIT" DAMAGE

FIG. 18a, b, AND c. TARGET 6. ROD DAMAGE TO "VICTOR" REAR FUSELAGE (LOW VEL. $\frac{1}{4}$in. ROD. STN. 940)

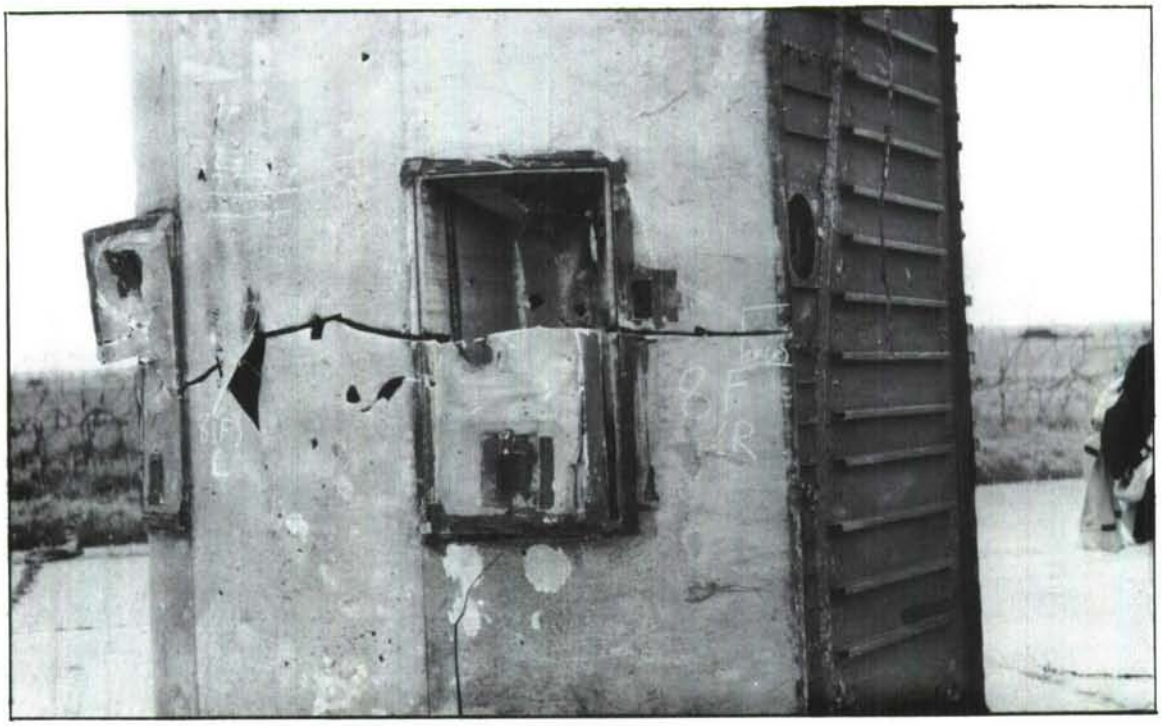


FIG. 19a. TARGET 7a. ROD DAMAGE TO TOP OF B 29 WING/FUSELAGE JUNCTION
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 434)

FIG. 19b. TARGET 7a. ROD "ENTRY" DAMAGE TO WING BOX TOP SURFACE INSIDE "B 29" FUSELAGE
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 434)

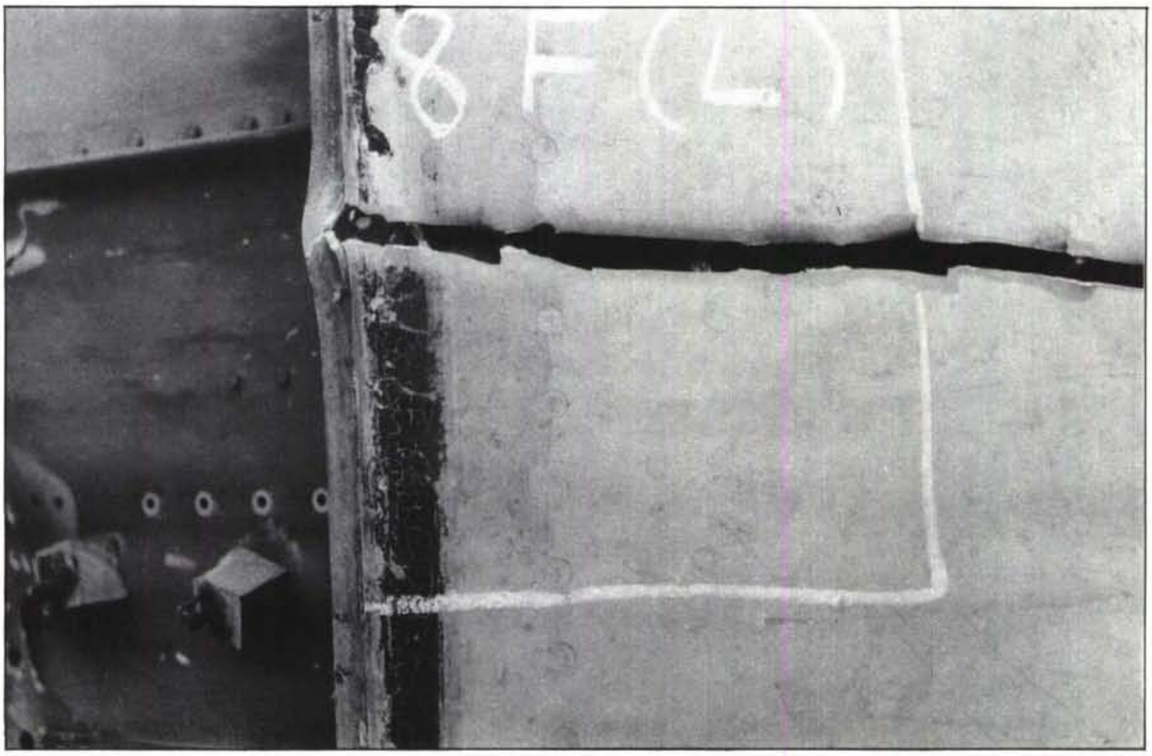


FIG. 19c. TARGET 7a. DETAIL OF ROD CUT END ON FUSELAGE STARBOARD SIDE (PORT SIDE SIMILAR)
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 434)

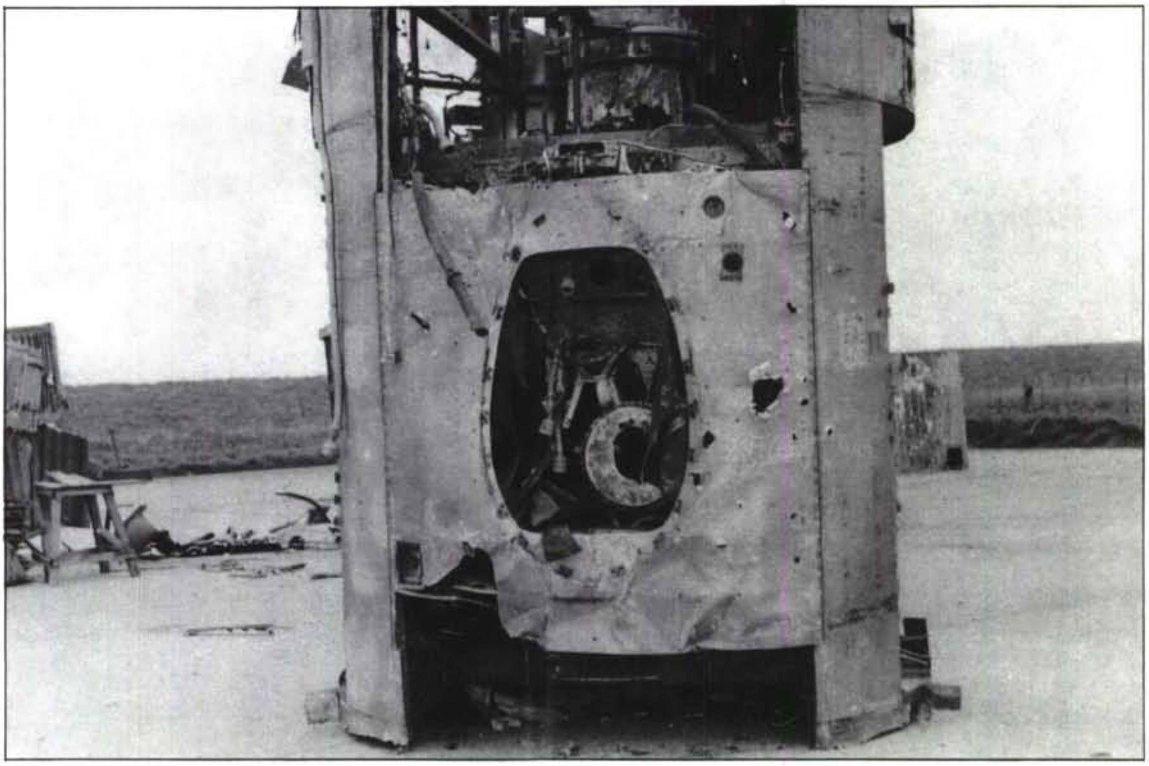


FIG. 19d. TARGET 7a. DAMAGE TO ROD EXIT SIDE OF B29 WING/FUSELAGE JUNCTION
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 434)

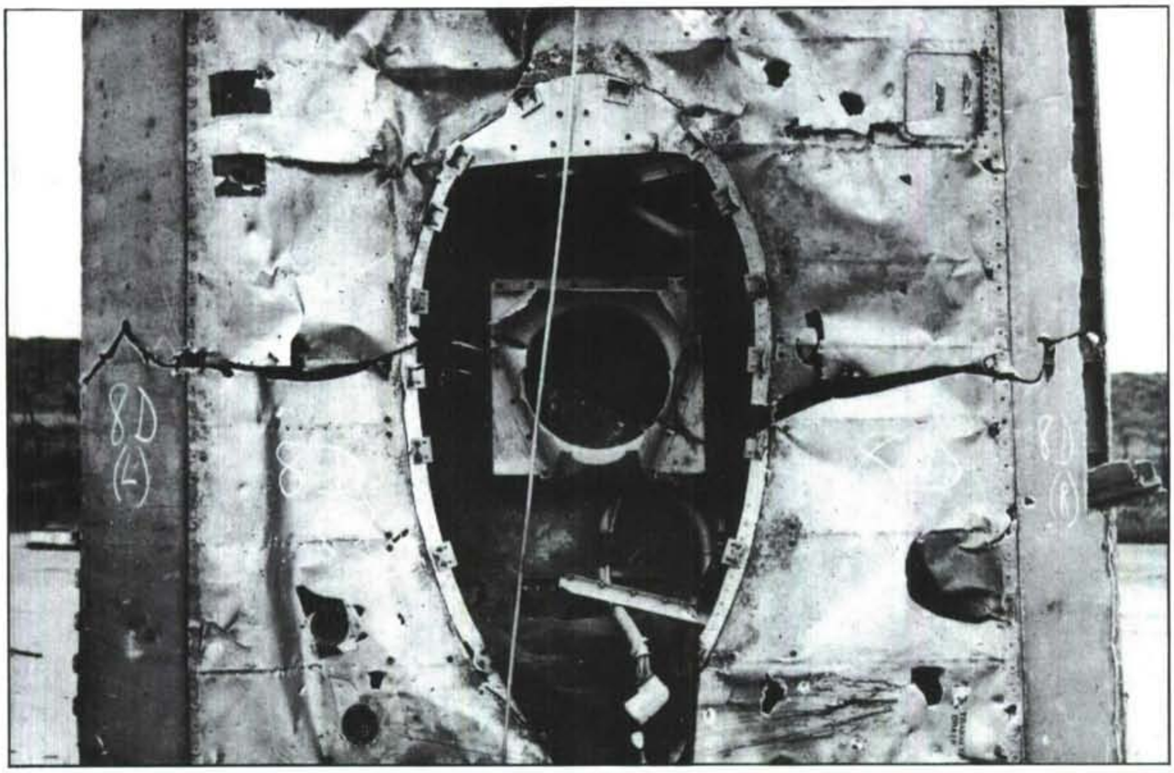


FIG.20a. TARGET 7b. ROD "ENTRY" DAMAGE TO BOTTOM OF B29 WING/FUSELAGE JUNCTION

(LOW VEL. $\frac{1}{4}$in. ROD. STN. 434)

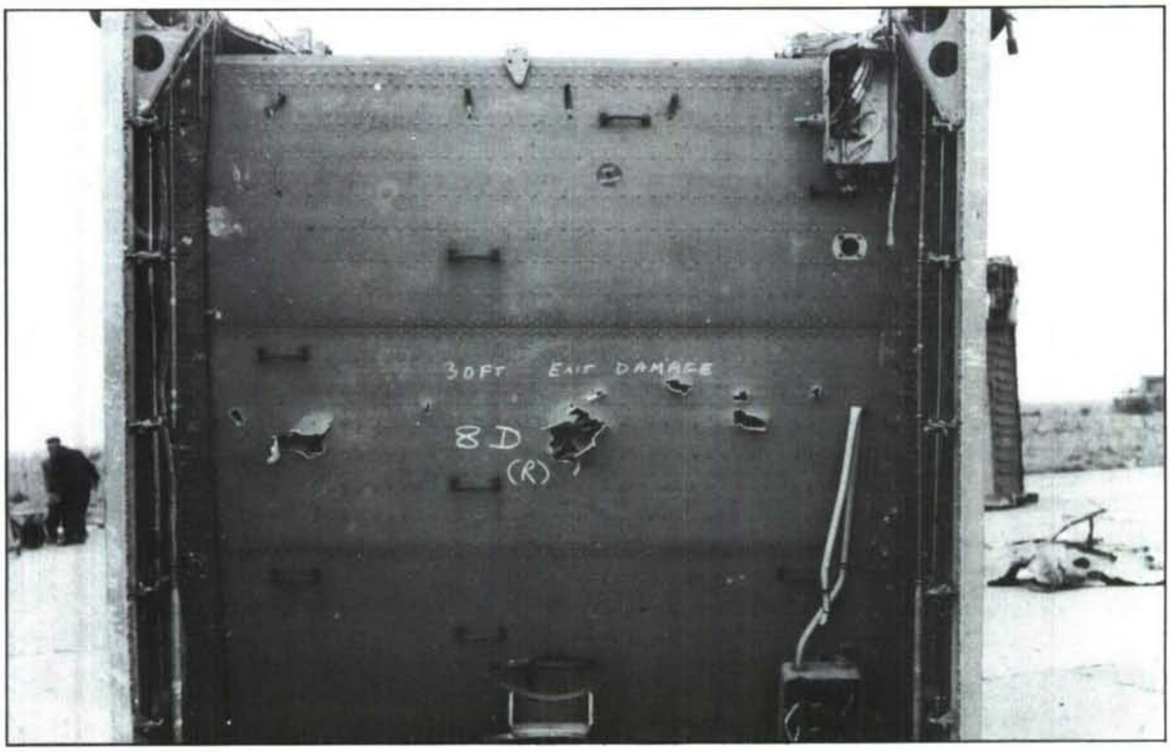


FIG.20b. TARGET 7b. ROD "EXIT" DAMAGE TO WING BOX TOP SURFACE INSIDE "B29" FUSELAGE

(LOW VEL. $\frac{1}{4}$in. ROD. STN. 434)

R.A.E: 164018 | 63

FIG.21a & b.

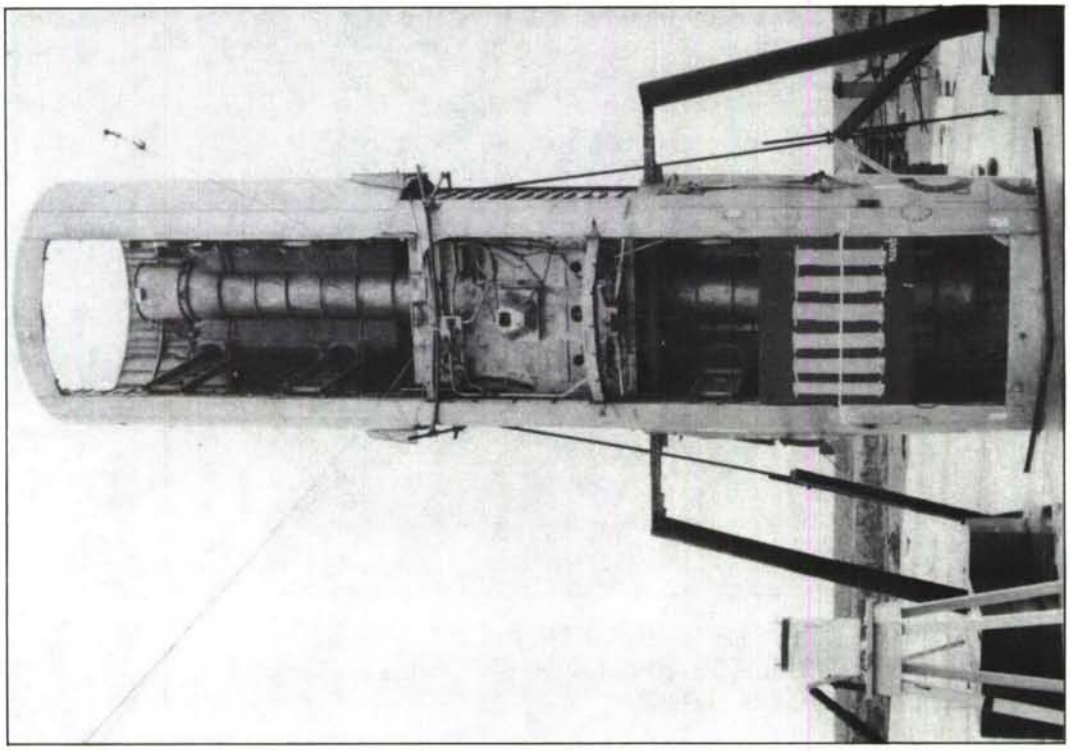


FIG.21a. TARGET 2. UNLOADED "B29" AFT BOMB BAY SECTION BEFORE ATTACK

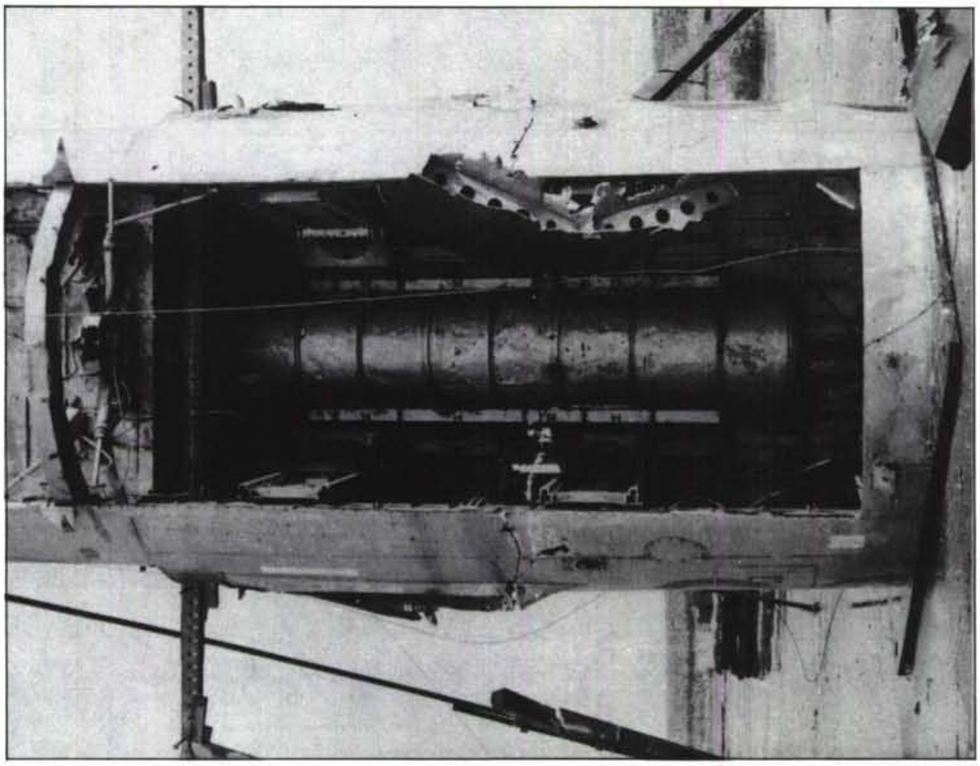


FIG.21b. TARGET 2. DAMAGE TO ROD "ENTRY" SIDE OF "B29" FUSELAGE

(LOW VEL. ¼in. ROD. STN. 566)

FIG.21c. TARGET 2. DAMAGE TO ROD "EXIT" SIDE OF "B29" FUSELAGE
(LOW VEL. $\frac{1}{4}$in. ROD. STN. 566)

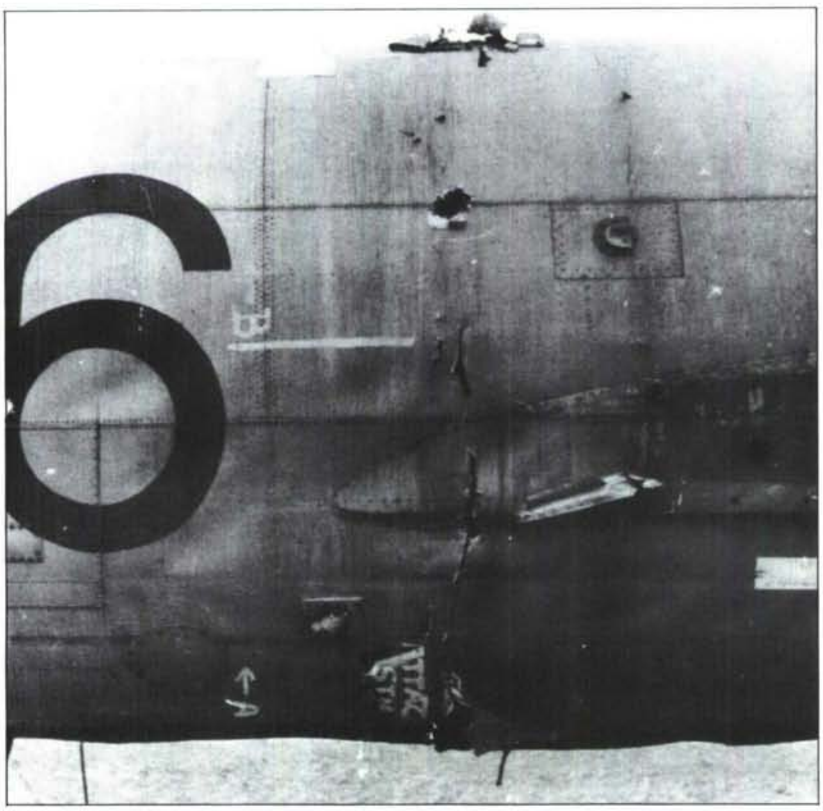


FIG.21d. TARGET 2. STARBOARD SIDE OF DAMAGED "B29" FUSELAGE UNDER SUBSEQUENT LOADING
NOTE:- SKIN WRINKLING

R.A.E. 164020 | 63

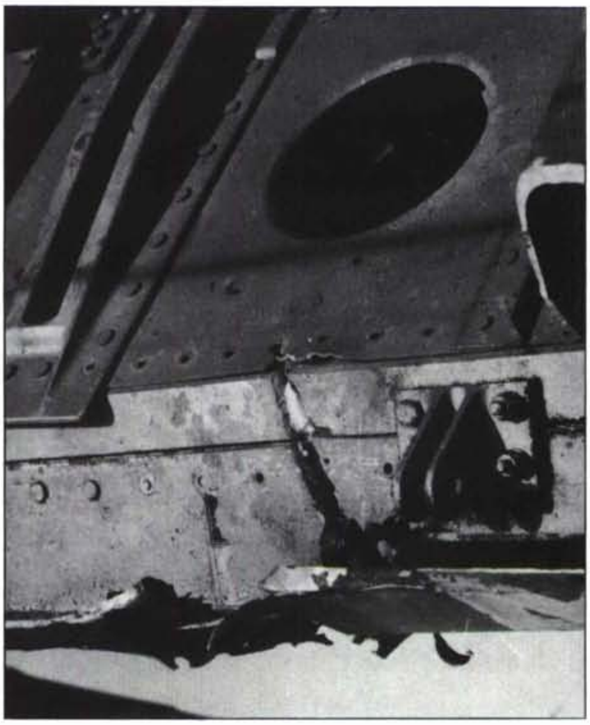


FIG.21e. STARBOARD LONGERON

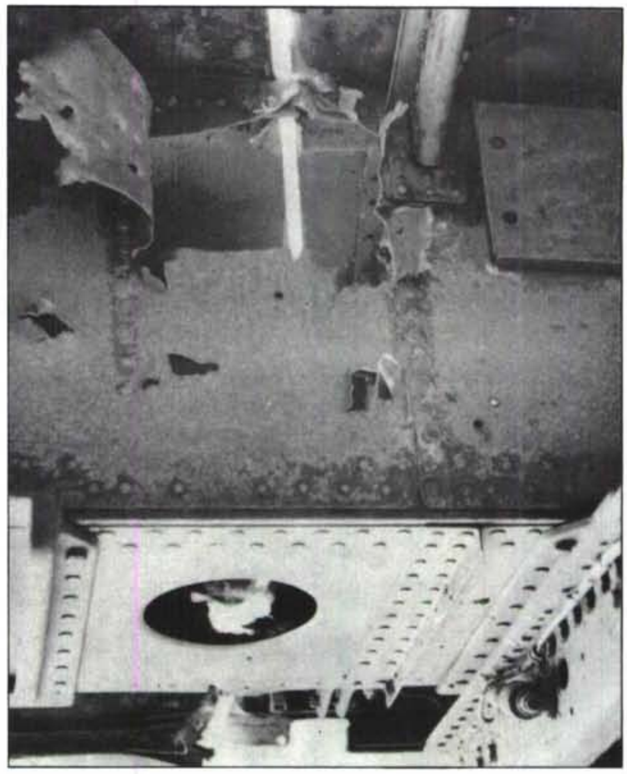


FIG.21f. STARBOARD CATWALK

FIG.21g. PORT LONGERON

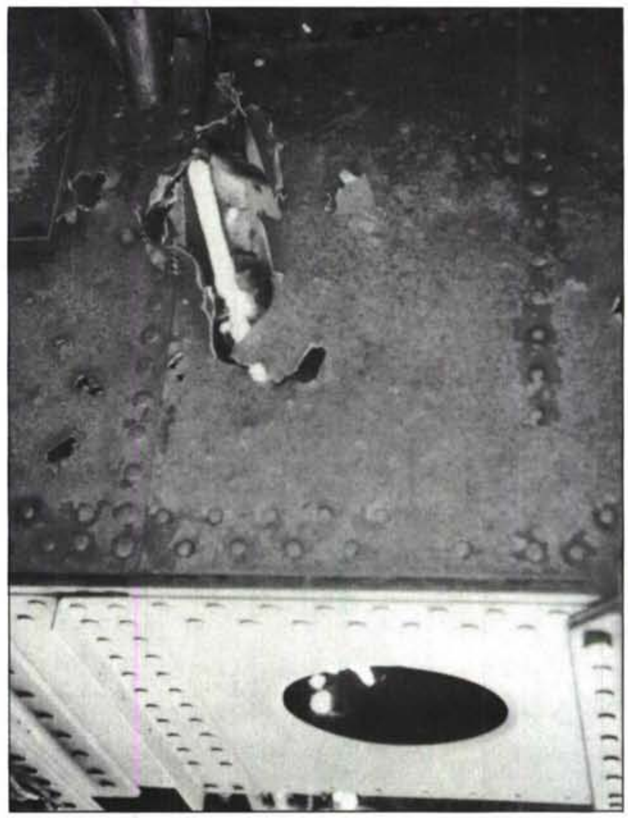


FIG.21h. PORT CATWALK

FIG.21e. to h. TARGET 2. ROD DAMAGE TO LONGERON STRUCTURE

(LOW VEL. $\frac{1}{4}$in. ROD. STN. 566)

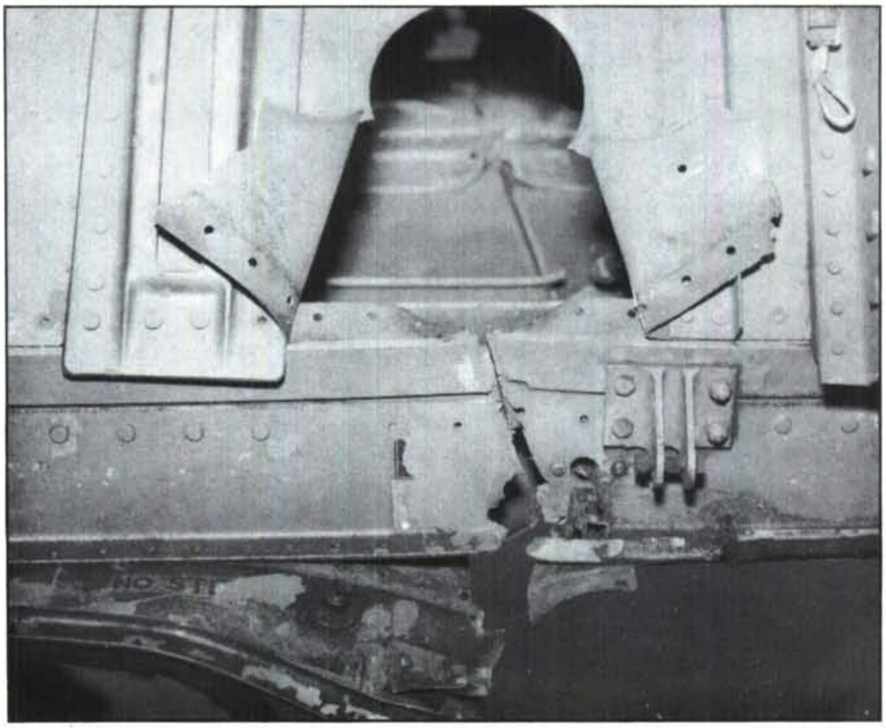


FIG.21j. STARBOARD LONGERON SHOWING PERMANENT DEFORMATION (COMPARE WITH FIG.21e.)

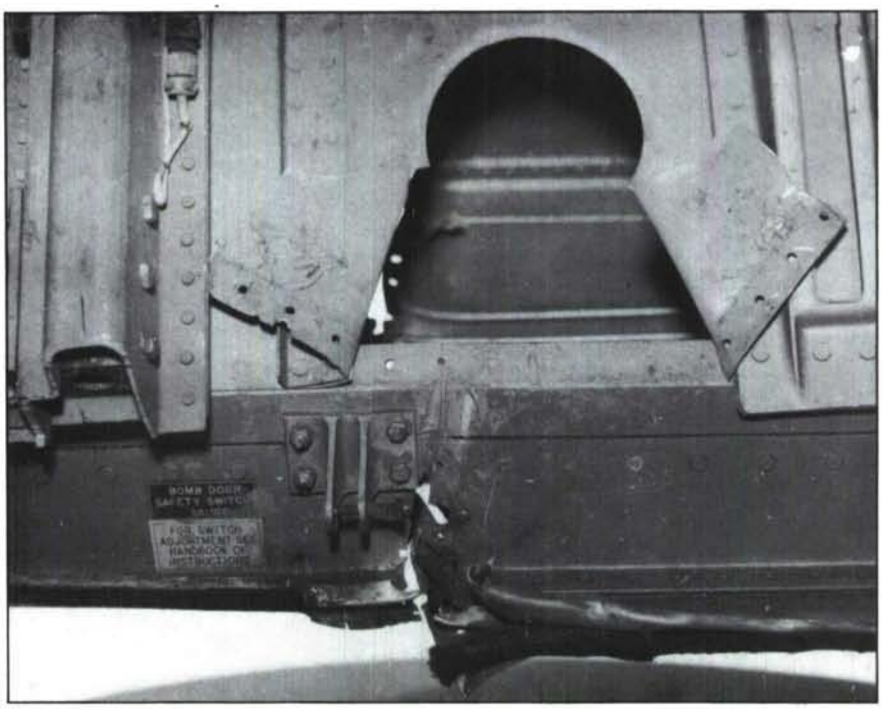


FIG.21k. PORT LONGERON (COMPARE WITH FIG.21g.)

FIG.21j. AND k. TARGET 2. DAMAGE TO LONGERONS AFTER ROD ATTACK, SEVERING, AND LOADING TO 2·3 g (LOW VEL. $\frac{1}{4}$in. ROD. STN. 566)

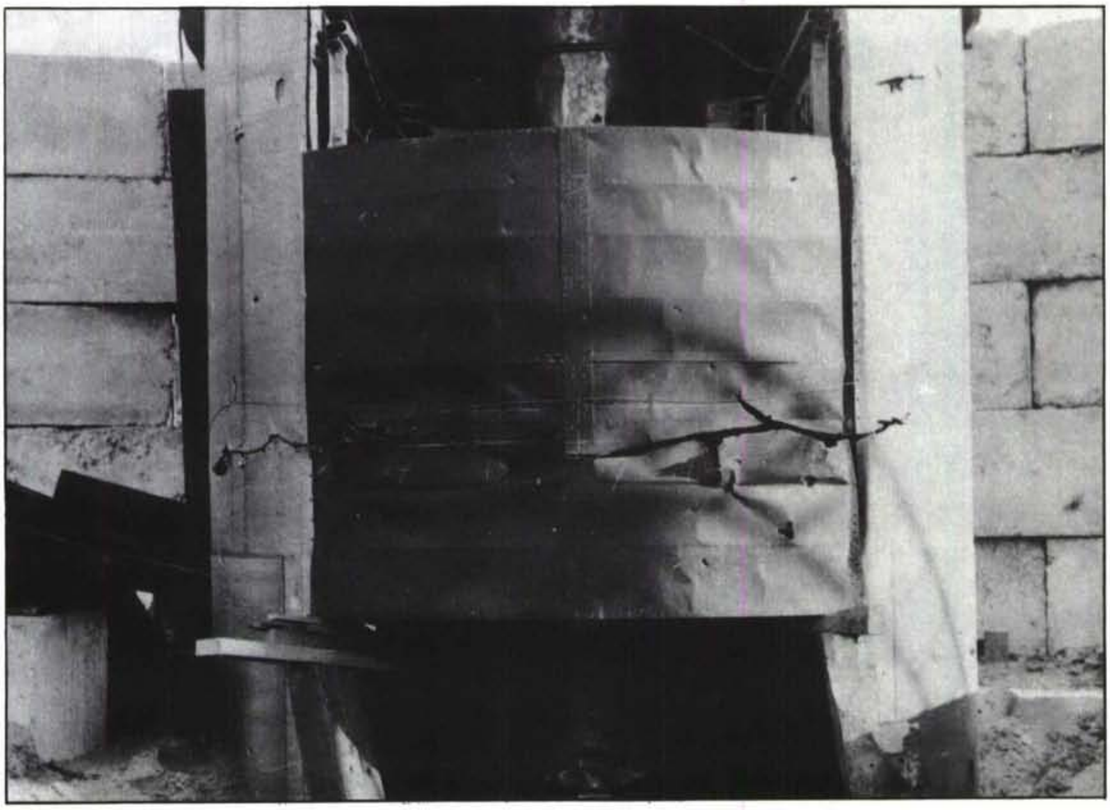


FIG.22a. TARGET 3b. DAMAGE TO ROD "ENTRY" SIDE OF UNLOADED "B29" FUSELAGE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 300)

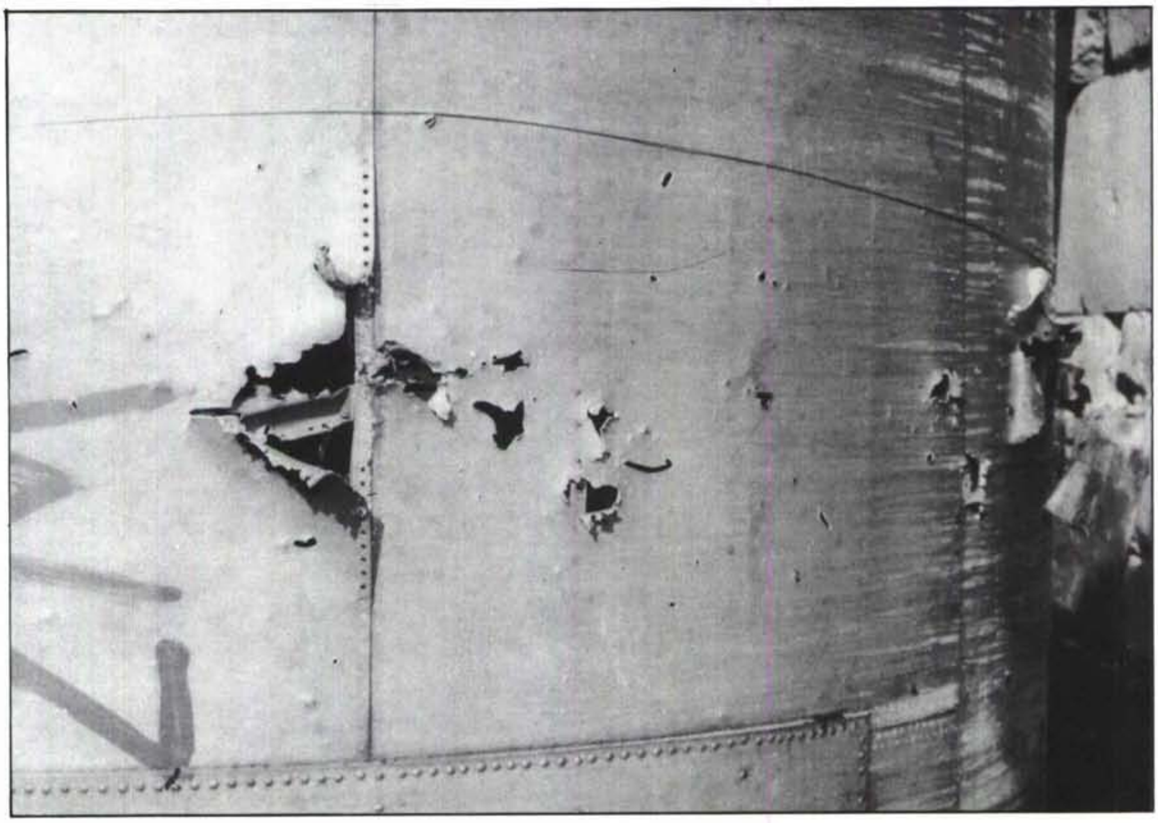


FIG.22b. TARGET 3b. DAMAGE TO ROD "EXIT" SIDE OF "B29" FUSELAGE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 300)

FIG.22c & d.

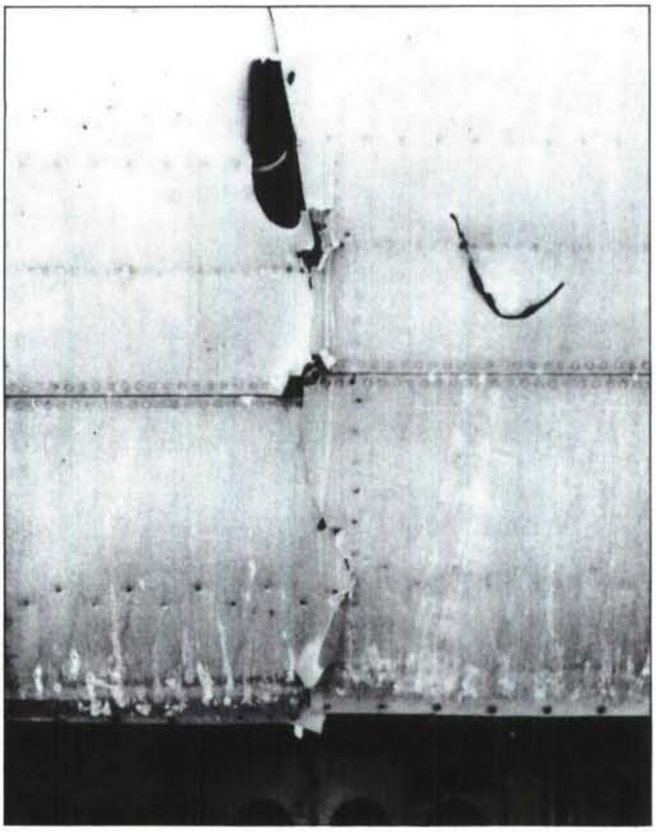


FIG.22c. PORT SIDE. NOTE:- SKIN BUTTING

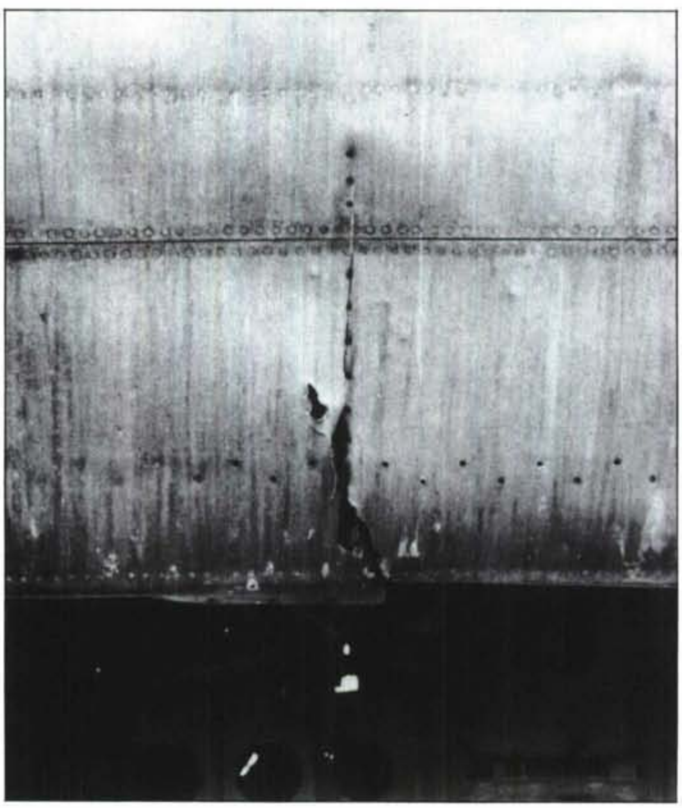


FIG.22d. STARBOARD SIDE

FIG.22c. AND 22d. TARGET 3b. ROD "ENTRY" SIDE DAMAGE UNDER SUBSEQUENT LOADING EQUIVALENT TO 2·8g

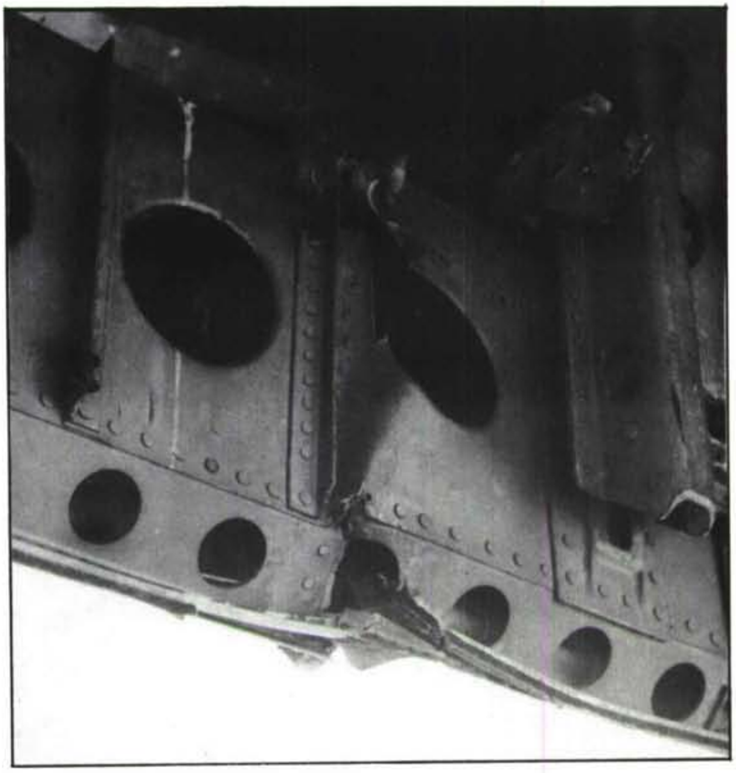


FIG.22e. PORT SIDE. NOTE:- BUTTING OF SEVERED MEMBERS

FIG.22f. STARBOARD SIDE. NOTE:- BUTTING OF SEVERED MEMBERS

FIG.22e. AND f. TARGET 3b. BEHAVIOUR OF SEVERED LONGERON MEMBERS UNDER SUBSEQUENT LOADING EQUIVALENT TO 2·8g.

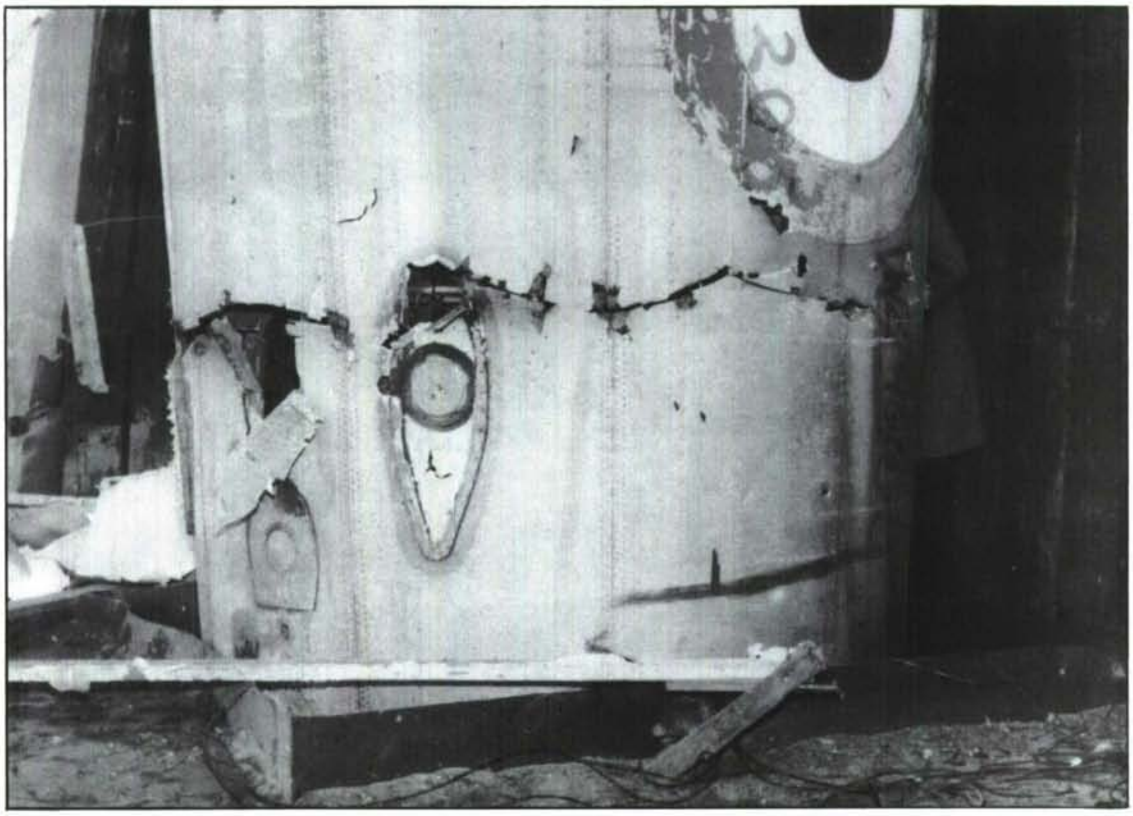


FIG.23a. TARGET 3a. DAMAGE TO ROD "ENTRY SIDE OF "1g" LOADED "B29" MID-CREW COMPARTMENT
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

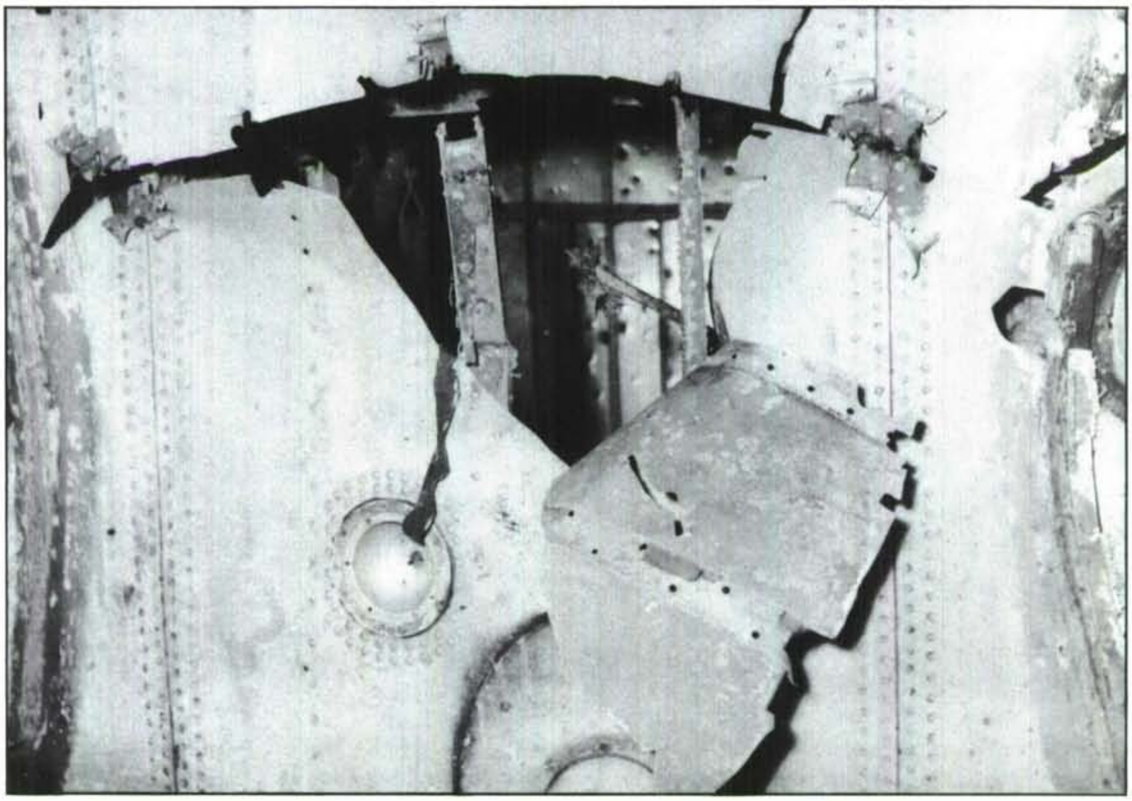


FIG.23b. TARGET 3a. DETAIL OF DAMAGE AT ROD CUT END ON STARBOARD SIDE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

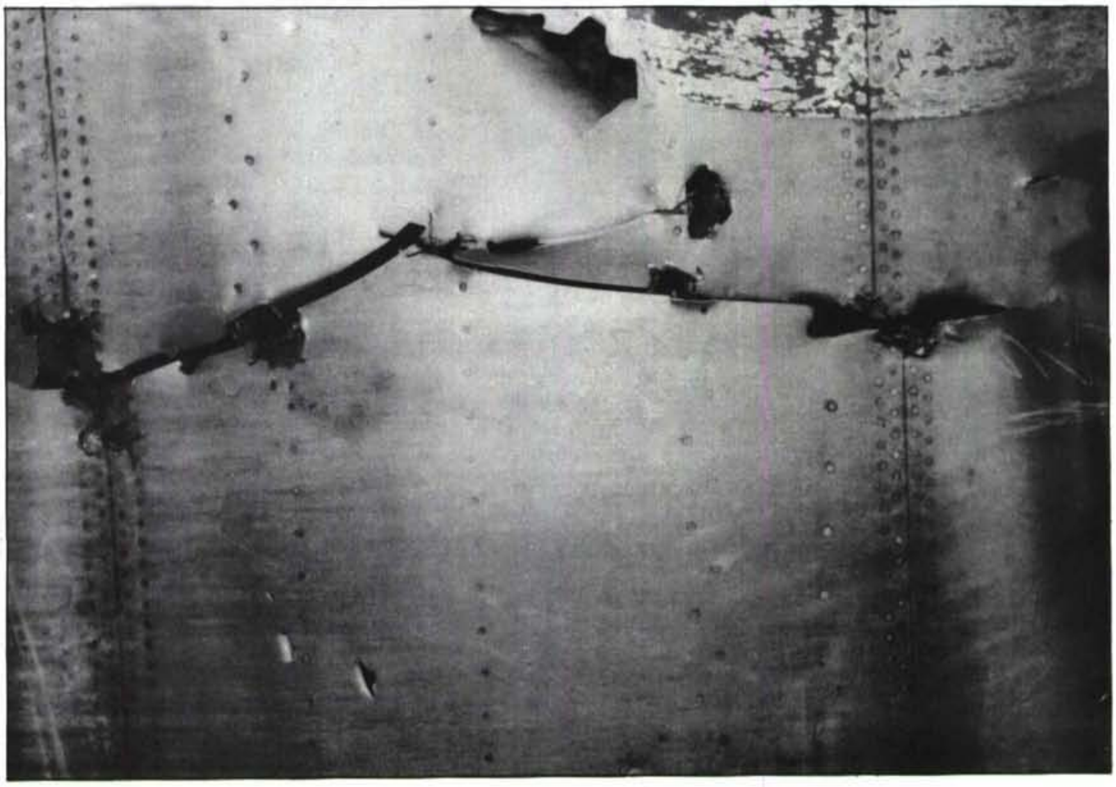


FIG.23c. TARGET 3a. DETAIL OF DAMAGE AT ROD CUT END ON PORT SIDE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

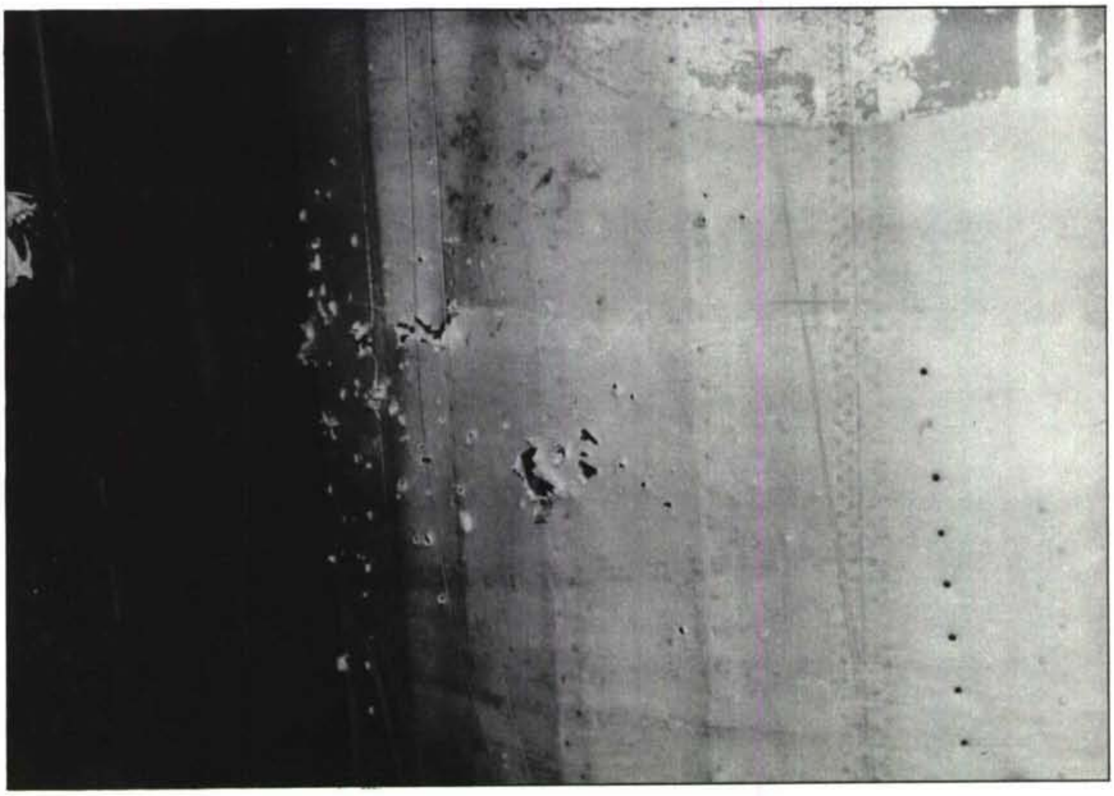


FIG.23d. TARGET 3a. DAMAGE TO ROD "EXIT" SIDE OF FUSELAGE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

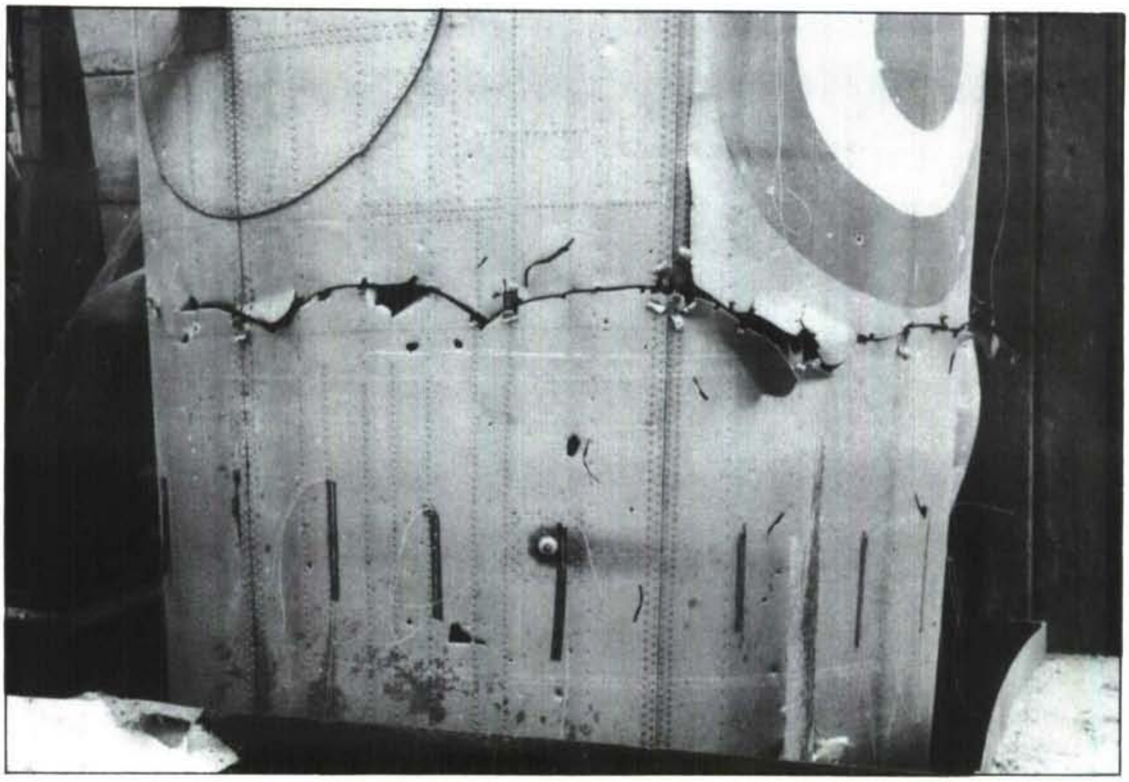


FIG.24a. TARGET 4a. DAMAGE TO ROD "ENTRY" SIDE OF UNLOADED "B29" MID-CREW COMPARTMENT
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

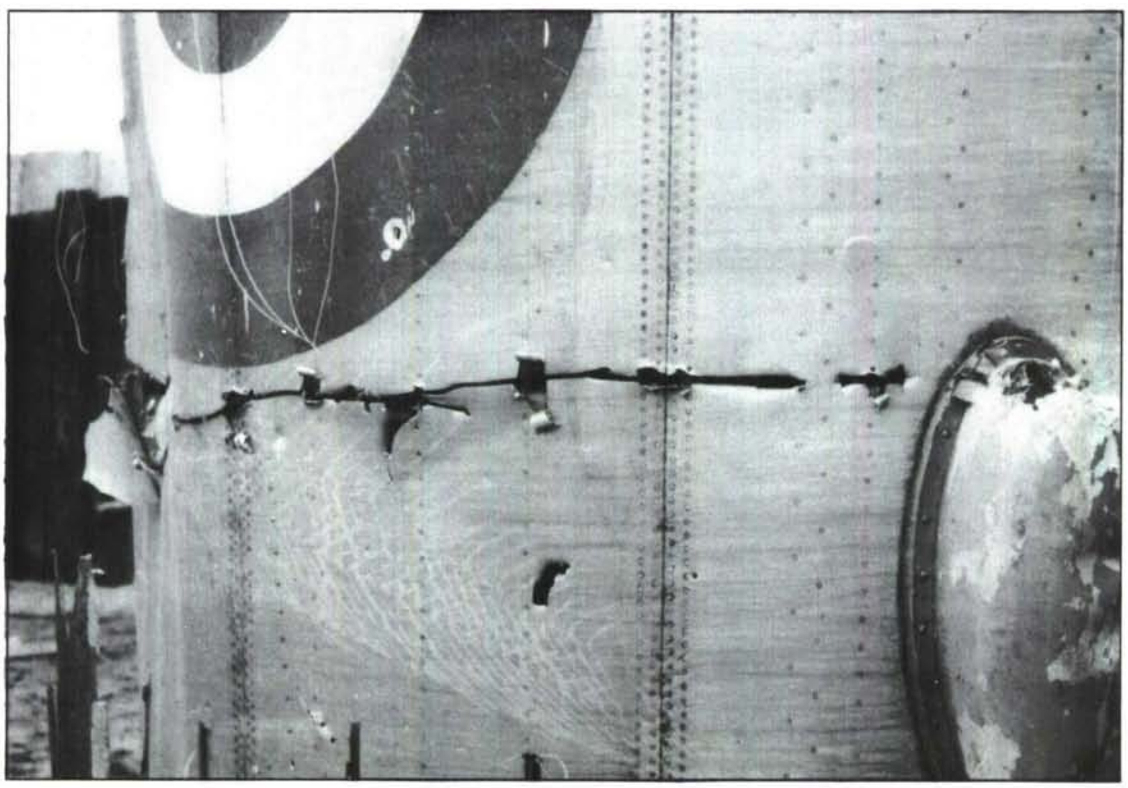


FIG24b. TARGET 4a. DETAIL OF DAMAGE AT ROD CUT END ON STARBOARD SIDE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

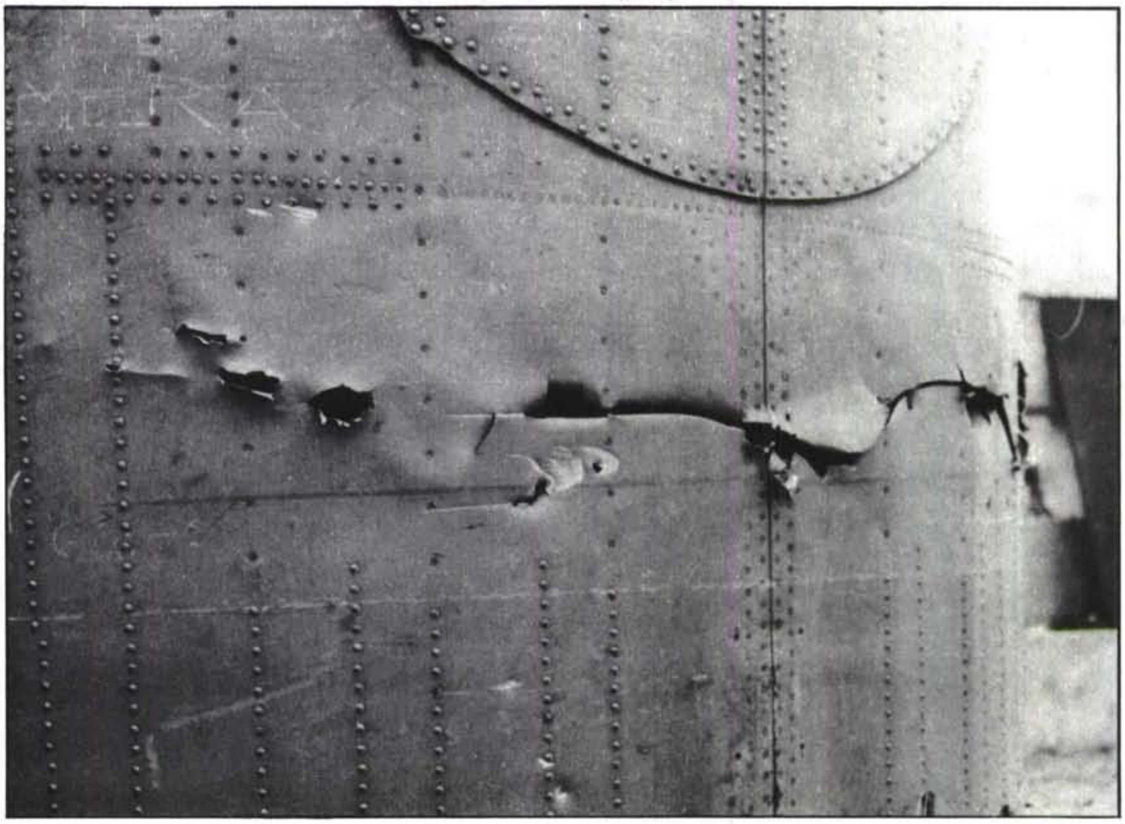


FIG24c. TARGET 4a. DETAIL OF DAMAGE AT ROD CUT END ON PORT SIDE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

FIG.24d. TARGET 4a. DAMAGE TO ROD "EXIT" SIDE OF FUSELAGE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

R.A.E. 164029 63

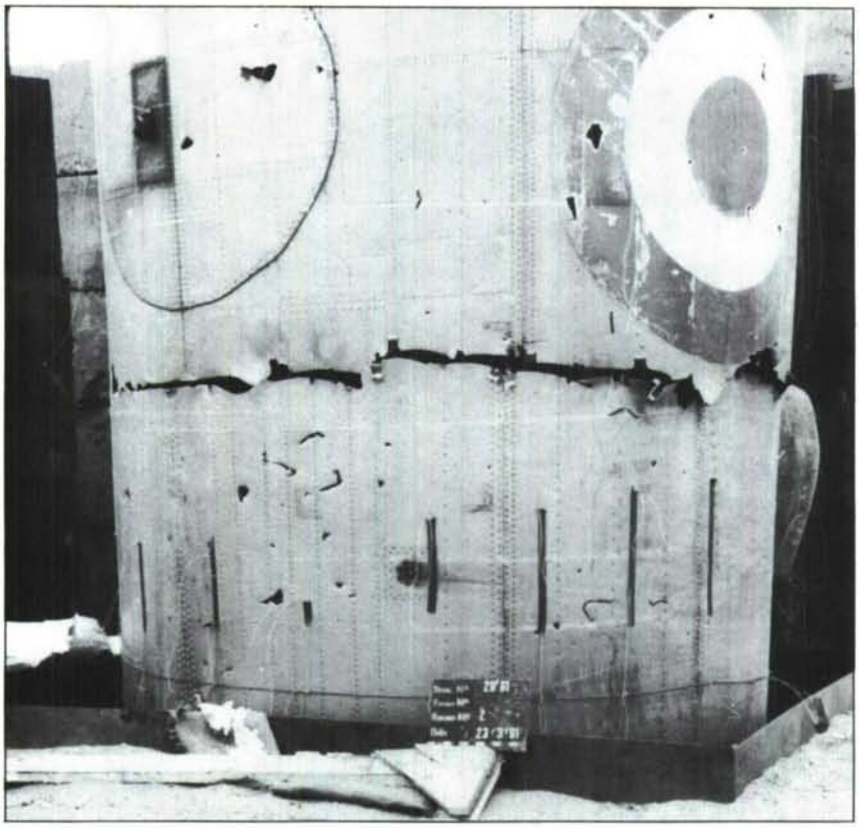


FIG.25a. TARGET 5a. DAMAGE TO ROD "ENTRY" SIDE OF "1 g" LOADED "B29" MID-CREW COMPARTMENT
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

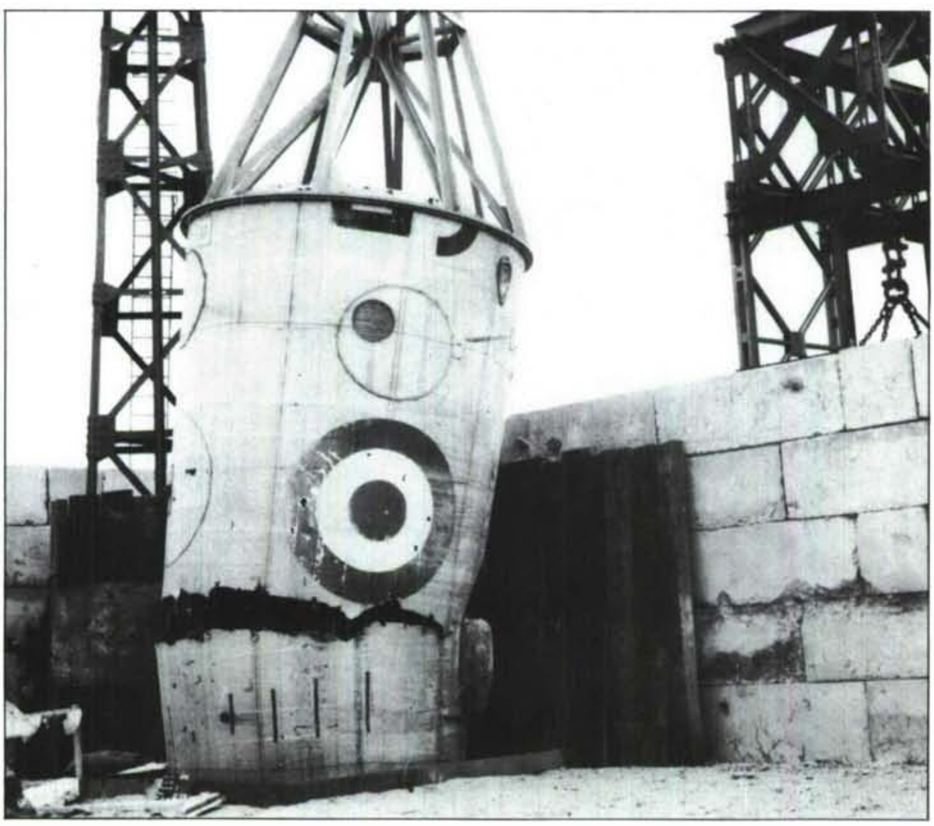


FIG.25b. TARGET 5a. FAILURE OF FUSELAGE UNDER SUBSEQUENT LOADING EQUIVALENT TO "1·8g"

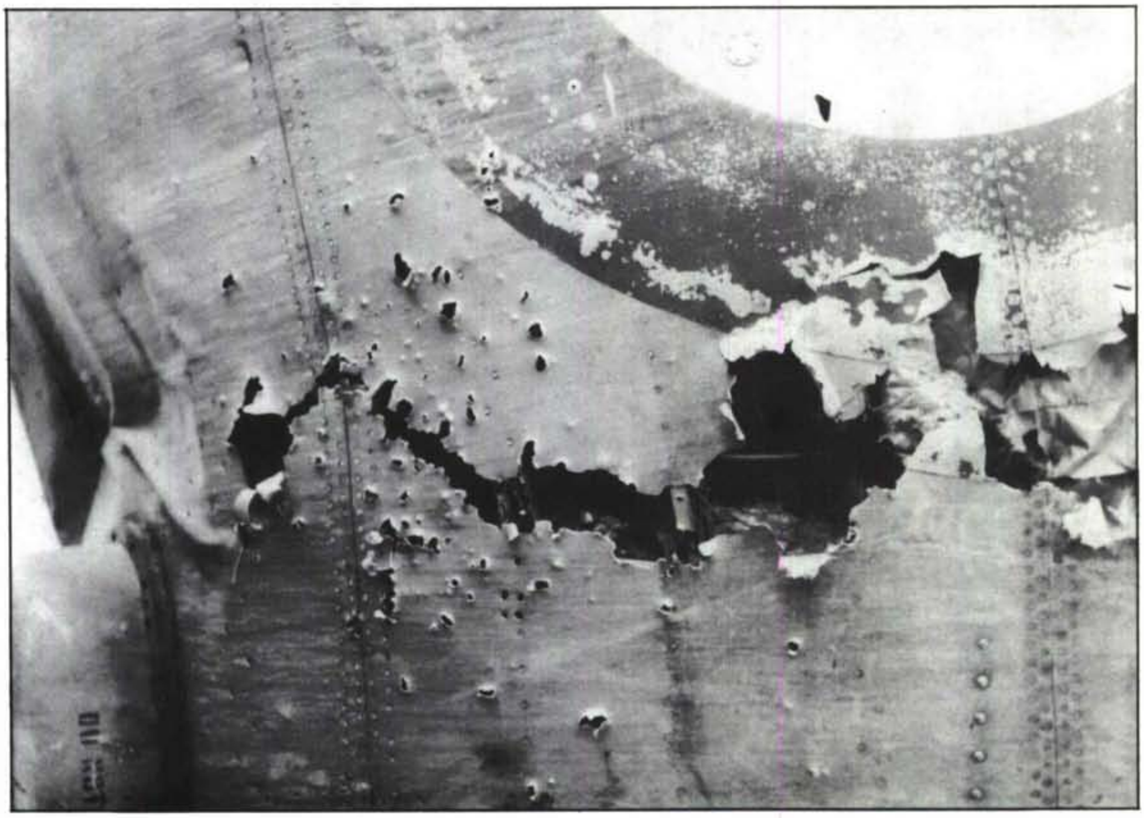


FIG.25c. TARGET 5a. DAMAGE TO ROD "EXIT" SIDE OF FUSELAGE AFTER SUBSEQUENT FAILURE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

FIG25d. TARGET 5a. DETAIL OF COMPRESSION LOADED SIDE OF FUSELAGE AFTER SUBSEQUENT FAILURE
(HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

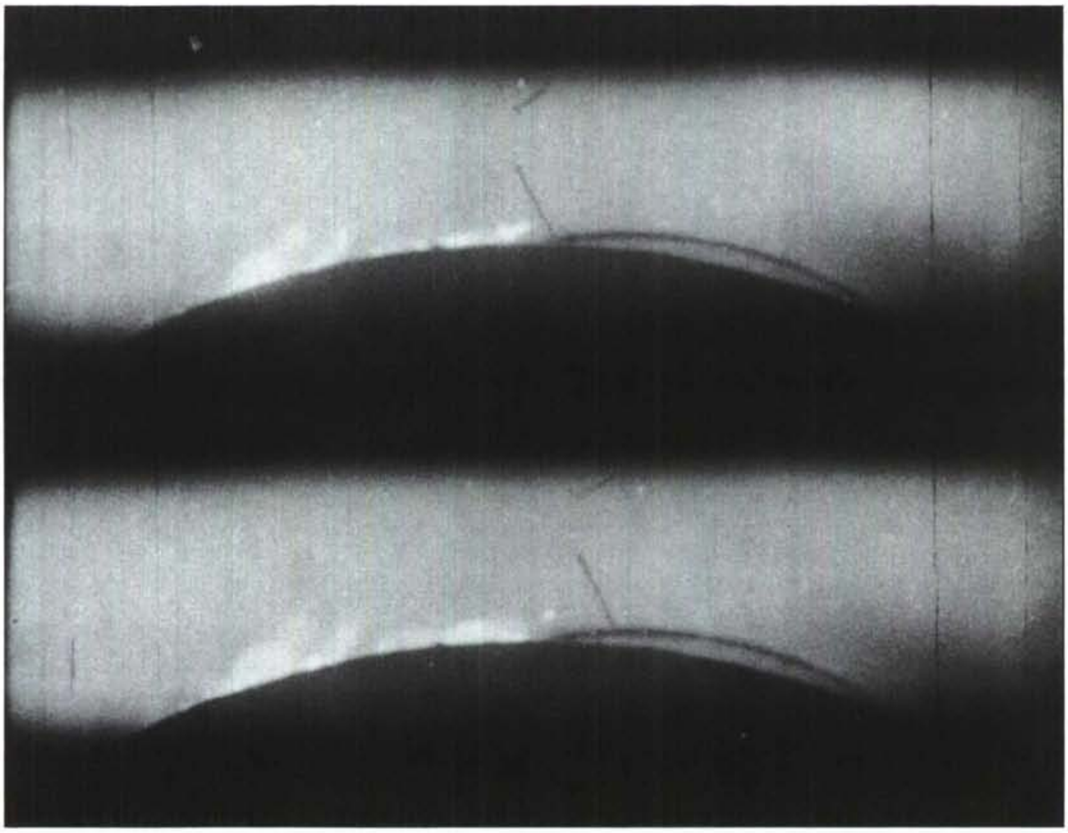


FIG.25e. TARGET 4a.
FIRING 4a.

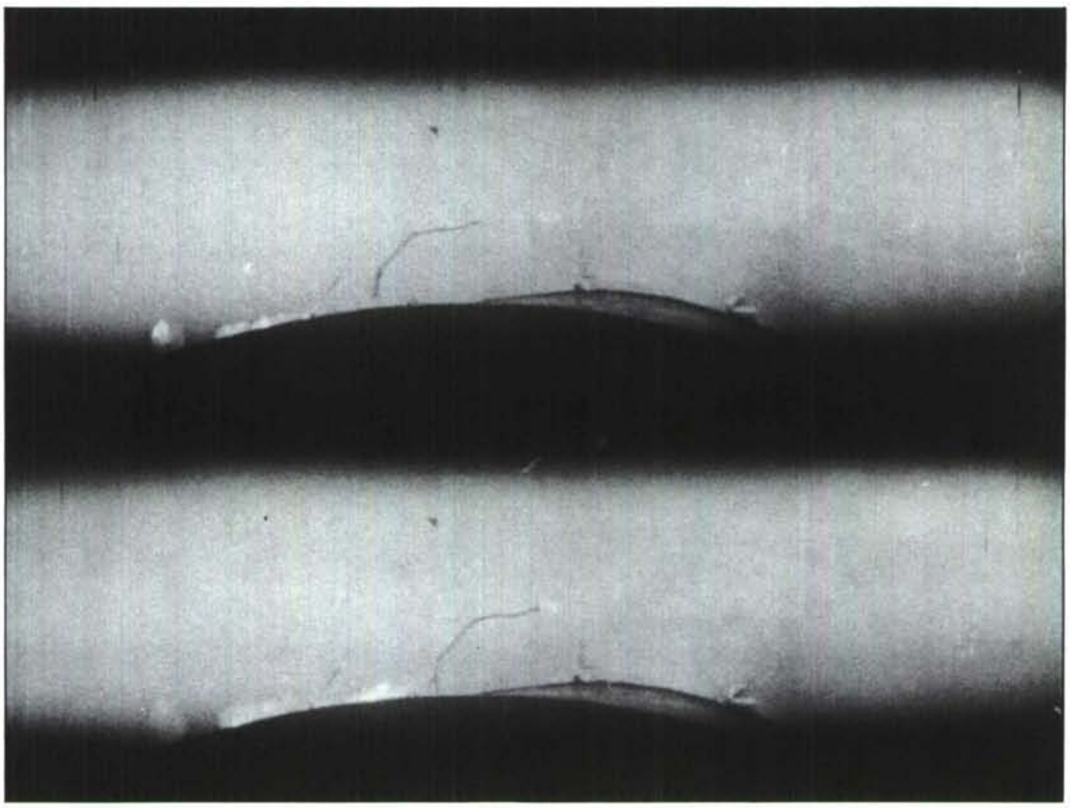


FIG.25f. TARGET 5a.
FIRING 5a.

FIG.25e AND f. ROD BEHAVIOUR NEAR END OF CUT ON "B29" FUSELAGE SECTIONS (HIGH VEL. $\frac{3}{16}$in. ROD. STN. 768)

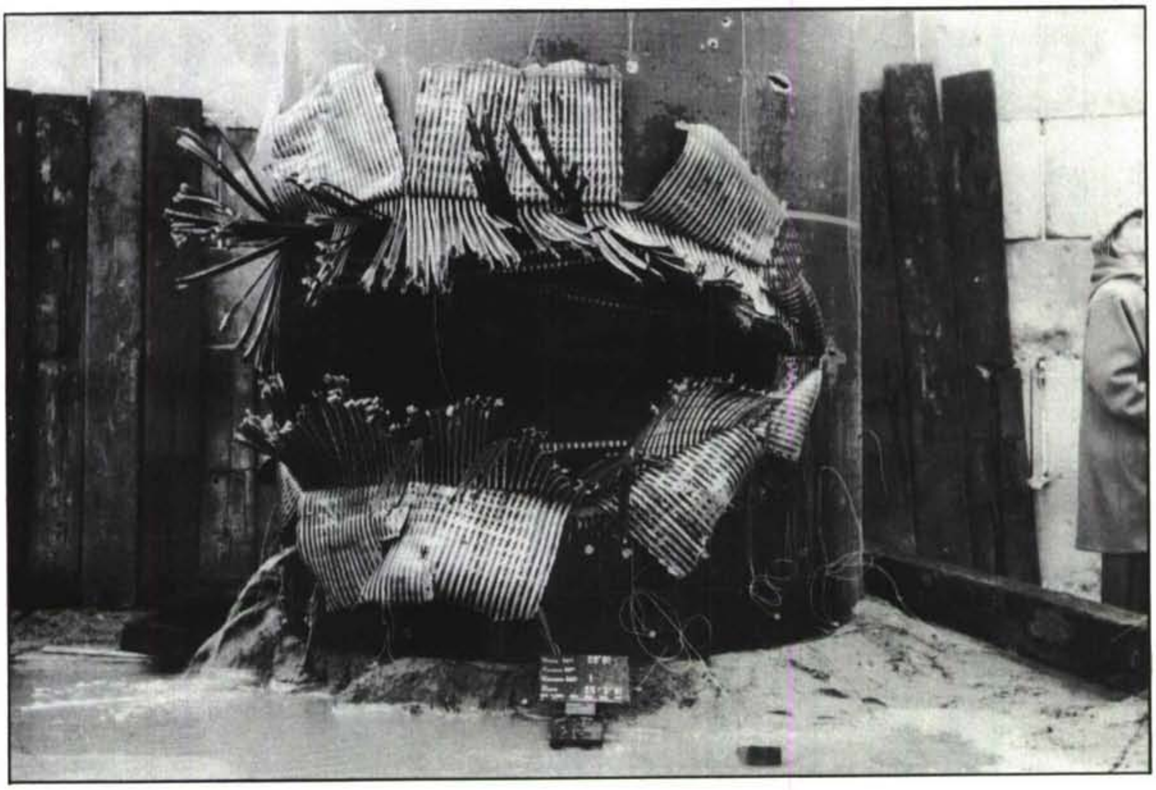


FIG.26. TARGET 4b. ROD DAMAGE TO WATER FILLED S.S.I TARGET
(HIGH VEL. $\frac{3}{16}$in. ROD)

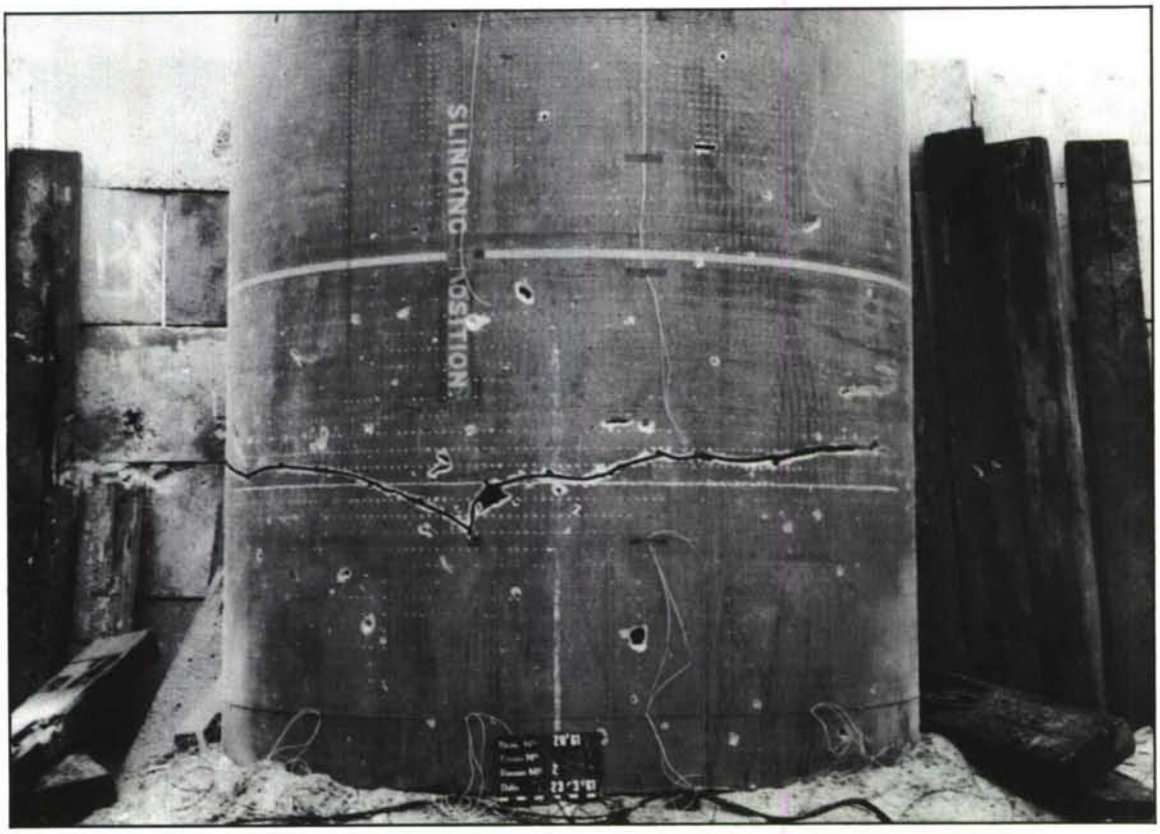


FIG.27. TARGET 5b. ROD DAMAGE TO SIMULATED EQUIPMENT FILLED S.S.I TARGET (NO "EXIT" DAMAGE)
(HIGH VEL. $\frac{3}{16}$in. ROD)

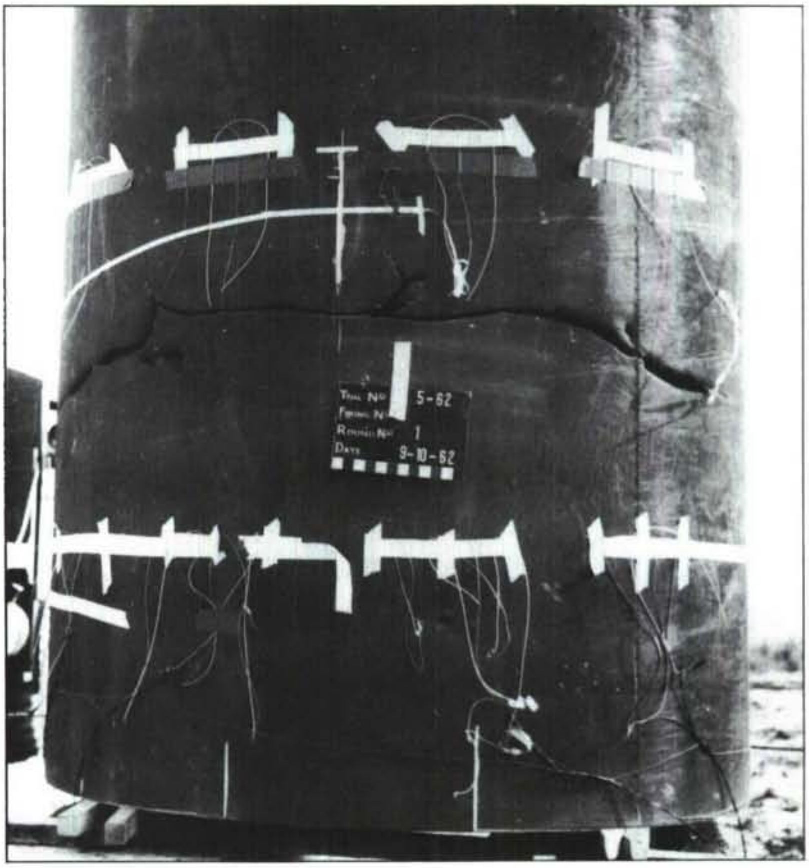


FIG.28a. TARGET 8. DAMAGE TO ROD "ENTRY" SIDE OF STEEL HONEYCOMB TARGET
(LOW VEL. $\frac{3}{16}$in. ROD)

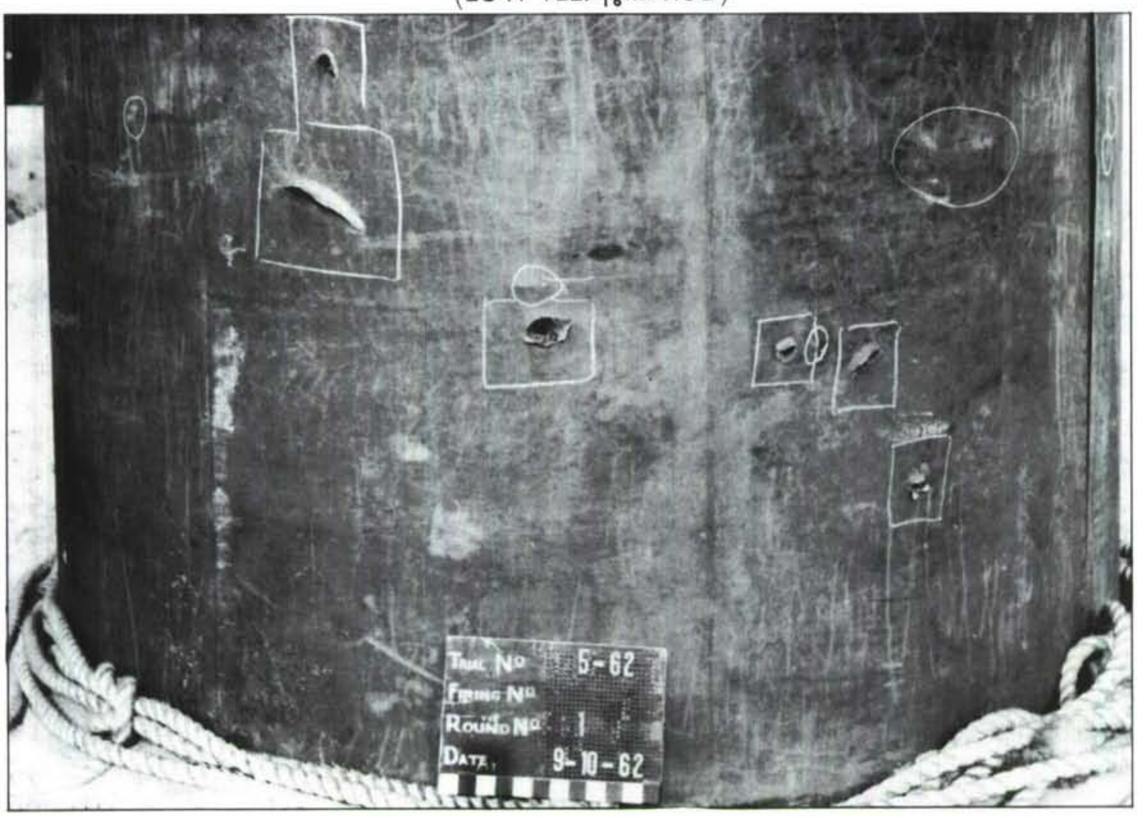


FIG28b. TARGET 8. ROD "EXIT" SIDE DAMAGE TO STEEL HONEYCOMB TARGET
(LOW VEL. $\frac{3}{16}$in. ROD)

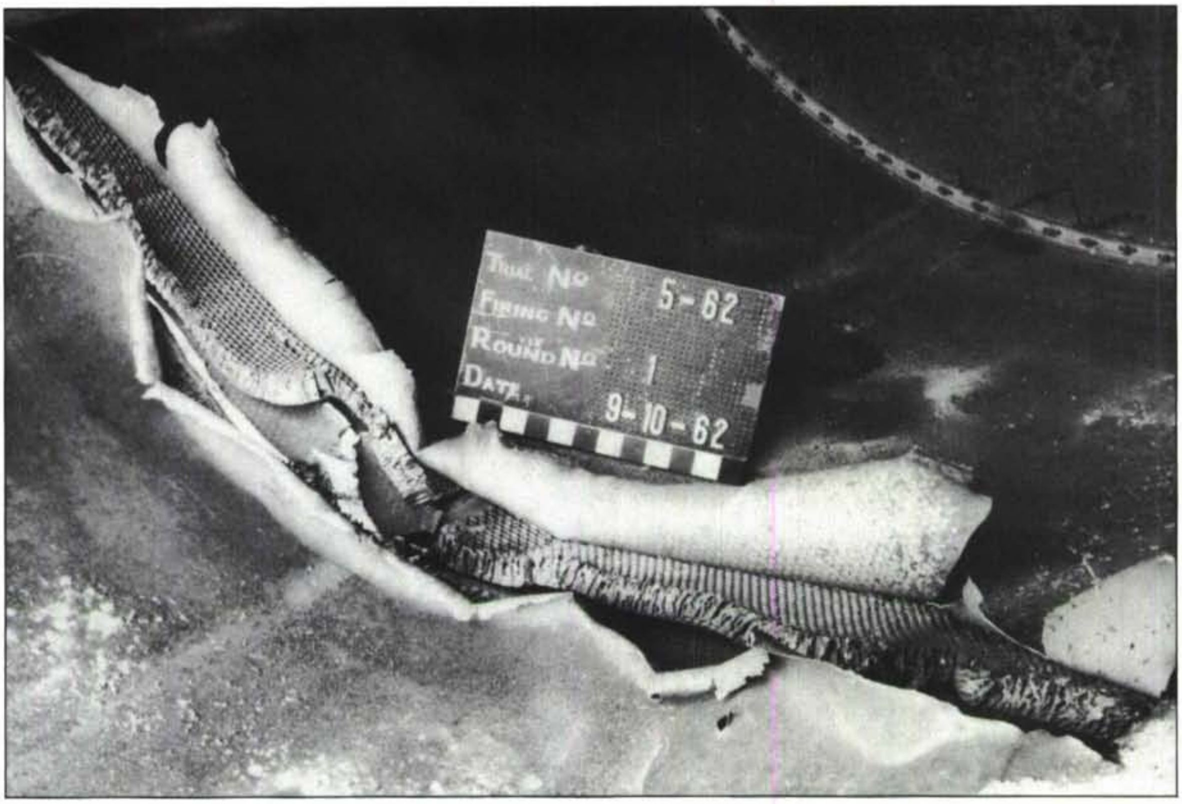


FIG.28c. TARGET 8. ROD DAMAGE TO HONEYCOMB CORE AND INNER SKIN
(LOW VEL. $\frac{3}{16}$in. ROD)

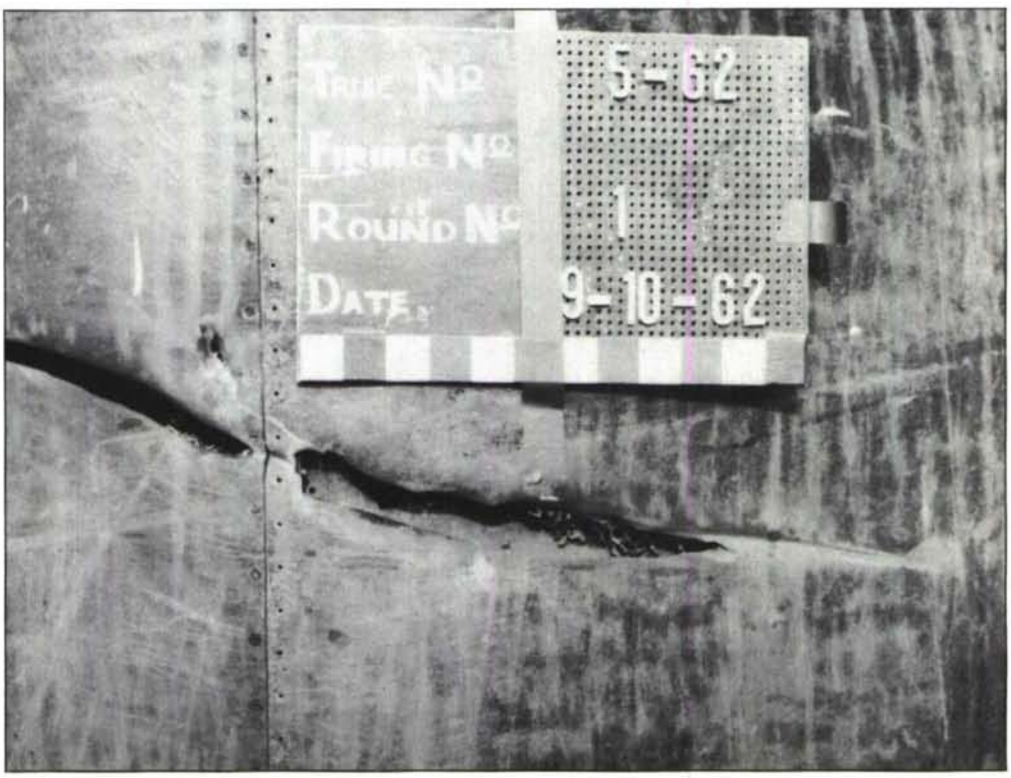


FIG.28d. TARGET 8. DETAIL OF TYPICAL ROD CUT END ON STEEL HONEYCOMB TARGET
(LOW VEL. $\frac{3}{16}$in. ROD)

APPENDIX 1

DETAILS OF TARGET LAYOUTS AND METHODS OF LOADING

(All figure numbers quoted refer to figures at the end of this Appendix)

1 TARGET LAYOUT

1.1 The attacks on thirteen aircraft fuselage sections described in this Note involved eight actual warhead firings. Thus, in five of the firings two fuselage sections were attacked simultaneously. It should also be noted that in several of the firings, other targets, such as aircraft wings etc, were included. The wing target attacks are to be reported in a separate Note.

In the case of the seven attacks in which the targets were loaded, three different loading methods were used and hence it is necessary to describe the target layouts and methods of loading used in each firing, as follows:-

1.2 Firing No.1

(a) In this firing, the Vickers 'Valiant' Type 673 was attacked in the '1g' loaded condition and the Handley Page 'Victor' second prototype in the unloaded state. For the purposes of the trial the 'Valiant' fuselage was assembled complete with inner wings and tail unit, and mounted as shown in Figs.1 and 5a.

It was desired that the target loading should produce stresses in the target, at the station attacked, representative of those occurring when the aircraft was flying straight and level in non-turbulent air at 0.81 M, at an all-up weight of 135,000 lb (i.e. with full bomb load and half fuel load). Owing to the complex loading system that would have been required to reproduce these stresses exactly, it was decided to load the fuselage by means of weights, placed on the aircraft tailplane, such that the errors in Bending Moment (B.M.) and Shear Force (S.F.), at the station attacked, were as small as possible. The required values of B.M. and S.F., together with the actual trials values were as follows:-

	Level flight values (1g) (Stn.963)	Trials values (Stn.963)
Bending moment (B.M.) Shear force (S.F.)	7,539,000 lb in. 30,680 lb	7,660,000 lb in. 31,540 lb

Counterbalance weights were provided in the form of sand and water in containers located in the pressure cabin, radome bay and forward services bay. Details of the fuselage section weights, applied loads and points of application are given in Fig.1.

(b) The secondary target in this firing consisted of the entire centre fuselage of the Handley Page 'Victor' second prototype mounted, for the firing, as shown in Figs.1 and 5a. After firing and re-mounting, loads were then applied to the damaged section by a combination of steel plates, acting through a wooden platform over the fin-root attachments, and by a vertical cable attached to the fin-post, passing through a pulley secured to a strong point in the ground, via a spring balance and to a tractor (see Fig.5b). The '1g' level flight B.M. and S.F., at the station attacked, when the aircraft is flying at 0.875 M and at an all-up weight of 116,200 lb (i.e. with full bomb load and half fuel load) are compared, below, with those applied at failure of the fuselage under load.

	Level flight values (1g) (Stn.740)	Approx. values at failure (Stn.740)
Bending moment (B.M.)	6,040,000 lb in.	5,680,000 lb in.
Shear force (S.F.)	18,800 lb	25,280 lb

The target layout and different loading methods used in Firing No.1 are shown in Fig.1.

1.3 Firing No.2

In this firing the primary target consisted of a 'B.29' centre fuselage, attacked in the unloaded condition, together with miscellaneous secondary targets (not dealt with in this Note) all positioned in a circular array round the warhead, as shown in Fig.2. For the firing, the fuselage section was mounted as shown in Fig.6a. To remove the axial load inherent in this mounting, the target was supported by means of a wooden beam passing under the rear spar and supported by wooden posts. After attack, the target was carefully assembled to the remainder of a B.29 fuselage and also the inner wings, as illustrated in Fig.6b. The attack station was then loaded by means of weights placed on the aircraft tailplane up to the equivalent of the '1g' loads occurring when the aircraft is flying in non-turbulent air at an all-up weight of 117,000 lb (i.e. with full bomb load and half fuel load). Since the fuselage did not fail, additional loading was imposed by a tractor and cable system similar to that used for the 'Victor' target after Firing No.1. The B.M. and S.F. at the attack station in level flight, and also at the maximum load it was possible to apply in the trial, were as follows:-

	Level flight values (1g) (Stn.566)	Maximum values applied (Stn.566)
Bending moment (B.M.)	4,763,000 lb in.	11,160,000 lb in.
Shear force (S.F.)	18,300 lb	25,710 lb

Details of the loading method are given in Figs.3 and 6b.

1.4 Firings Nos.3, 4 and 5

These three firings were made using the Pendine long test track. For each firing, the warhead was mounted on the front end of a two-stage rocket propelled vehicle as shown in Fig.7d. The warhead was then propelled along the track and detonated on an expendable section of rail near the centre of a circular arena containing two aircraft fuselage sections and other miscellaneous targets, as shown in Figs.7a and 7b.

(a) In each firing the primary target, a B.29 mid-crew compartment, either loaded during attack, or subsequently loaded, by means of a loading rig (Fig.7c) consisting of a ground frame to one end of which the target was bolted. To the other end of the frame, a tower, also of Bailey bridge structure was secured. Two tower locations were provided on the frame. A triangulated loading arm was attached to the upper end of the target at Stn.646 and, for the two firings against the fuselage tension loaded surfaces, a cable was attached to the apex of the arm and thence over a pulley in the top of the tower to a large tank suspended within the tower and whose weight gave the required '1g' B.M. and S.F. at the target attack station. If the target did not fail under attack the forces at the attack station could be increased to the '2g' condition by filling the tank with water.

In the case where the target compression surface was attacked the second tower position was used (Fig.7b) and the cable loading system replaced by a strut connected by a cable to the water tank so that a pushing force was applied to the loading arm apex and hence to the target. The B.M's and S.F's, at the station attacked, for '1g' level flight conditions in non-turbulent air at an all-up weight of 117,000 lb (full bomb load and half fuel load), are given below together with the actual trials values:-

	Level flight values (1g) Stn.768	Target No.3A		Target No.4A		Target No.5A	
		During attack	Max. values applied	During attack	Max. values applied	During attack	At failure
Bending moment (B.M.)	2,314,000 lb in.	2,420,000 lb in.	4,700,000 lb in.	Not loaded	4,980,000 lb in.	2,495,000 lb in.	4,210,000 lb in.
Shear force (S.F.)	8225 lb	8600 lb	16,600 lb	Not loaded	17,679 lb	8,864 lb	14,884 lb

The small discrepancies between the required level flight values and the trials values are due to practical difficulties of loading; they are, however, well within the range of fluctuating values to be expected in level flight.

(b) In two of the firings, the secondary targets (4B and 5B) consisted of replica steel supersonic fuselage sections not designed to be loaded. They were mounted, relative to the track, at the position shown in Figs.4 and 7a.

In the third firing the secondary target (3B) was a B.29 centre fuselage mounted in a similar position, as shown in Fig.7b. After attack in the unloaded condition, the target was assembled to the remaining sections of a 'B.29' fuselage

and also the inner wings, as shown in Fig.8a. In this case, the required counterbalance weights were applied to the aircraft tailplane, as illustrated in Fig.8b, the tail being supported by a cradle. The attack station was then loaded up to '1g' level flight conditions by means of water-filled tanks positioned in the pressure cabin. Since failure did not occur, additional load was applied, by the previously described tractor and cable system, to the nosewheel pivot point, up to the maximum achievable. This load was then relaxed and re-applied five times in quick succession in order to simulate gust loading conditions. Failure did not result.

The B.M's and S.F's at the attack station for '1g' level flight in non-turbulent air at an aircraft all-up weight of 117,000 lb (with full bomb load and half fuel load) are given below together with the maximum applied during the loading procedure:-

	Level flight values (1g) (Stn.300)	Maximum values applied (Stn.300)
Bending moment (B.M.)	2,174,400 lb in.	6,175,700 lb in.
Shear force (S.F.)	13,809 lb	29,200 lb

Target layouts for Firings Nos.3, 4 and 5 are shown in Figs.4, 7a and 7b and the loading method for Targets 4A, 5A in Fig.7c. Fig.7b shows the loading system for Target 3A.

1.5 Firings Nos.6, 7 and 8

Four fuselage specimens (Nos.6, 7A, 7B and 8) included in these firings were secondary targets in layouts involving miscellaneous other targets not dealt with in this Note. They were not suitable for loading either during or after attack, and were positioned in the target arenas with their longitudinal axes vertical and resting on one end. All sustained circumferential rod cuts except that in Firing No.8 where the cut was inclined at approximately 30° to the normal to the fuselage surface.

ATTACHED:

Figs.1-4 Drg. Nos. SME 88695/R - 88698/R
Figs.5-8 Neg. Nos. 164,036 - 164,040

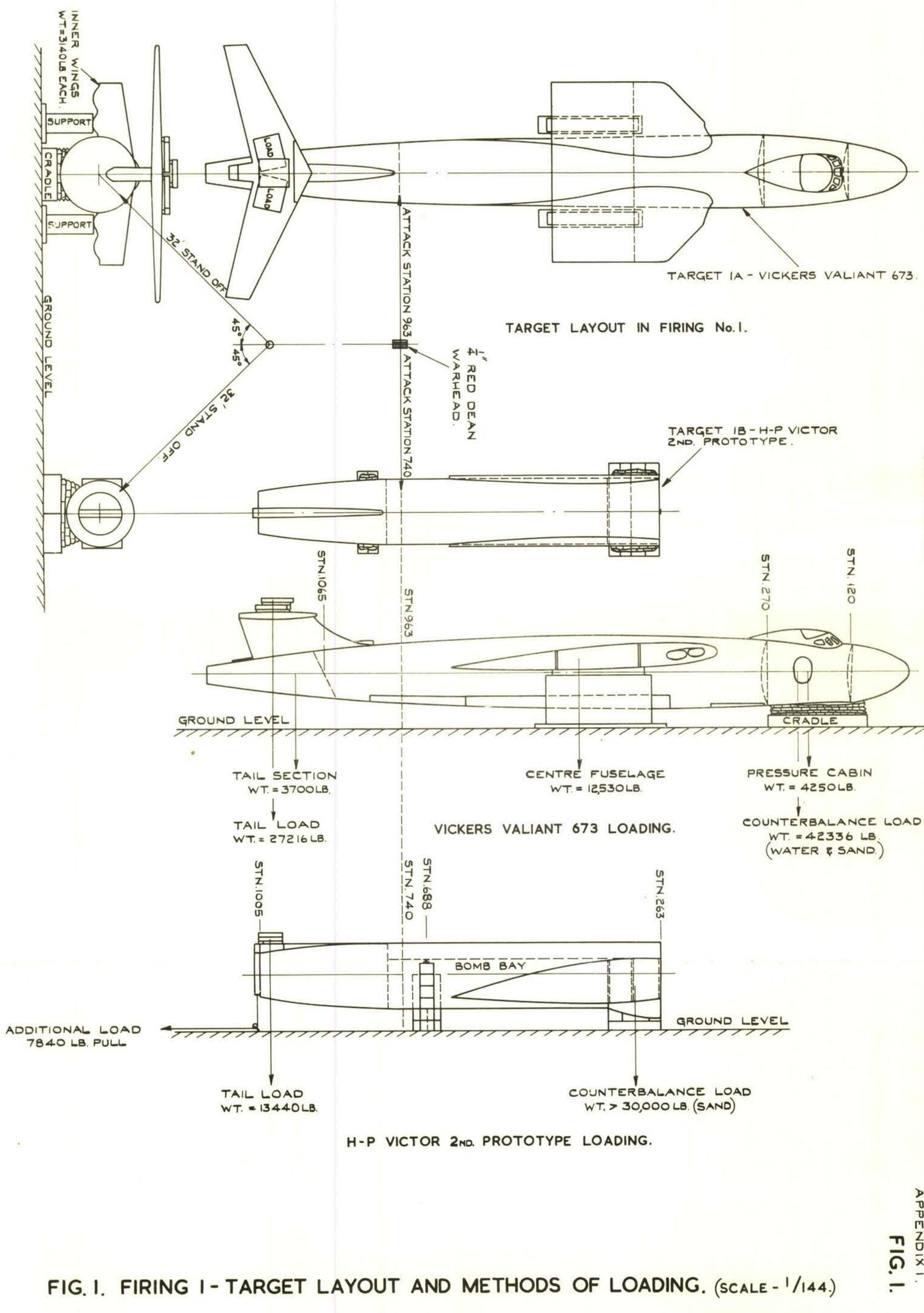


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FIG. I. FIRING I - TARGET LAYOUT AND METHODS OF LOADING. (SCALE - 1/144.)

FIG. 2.

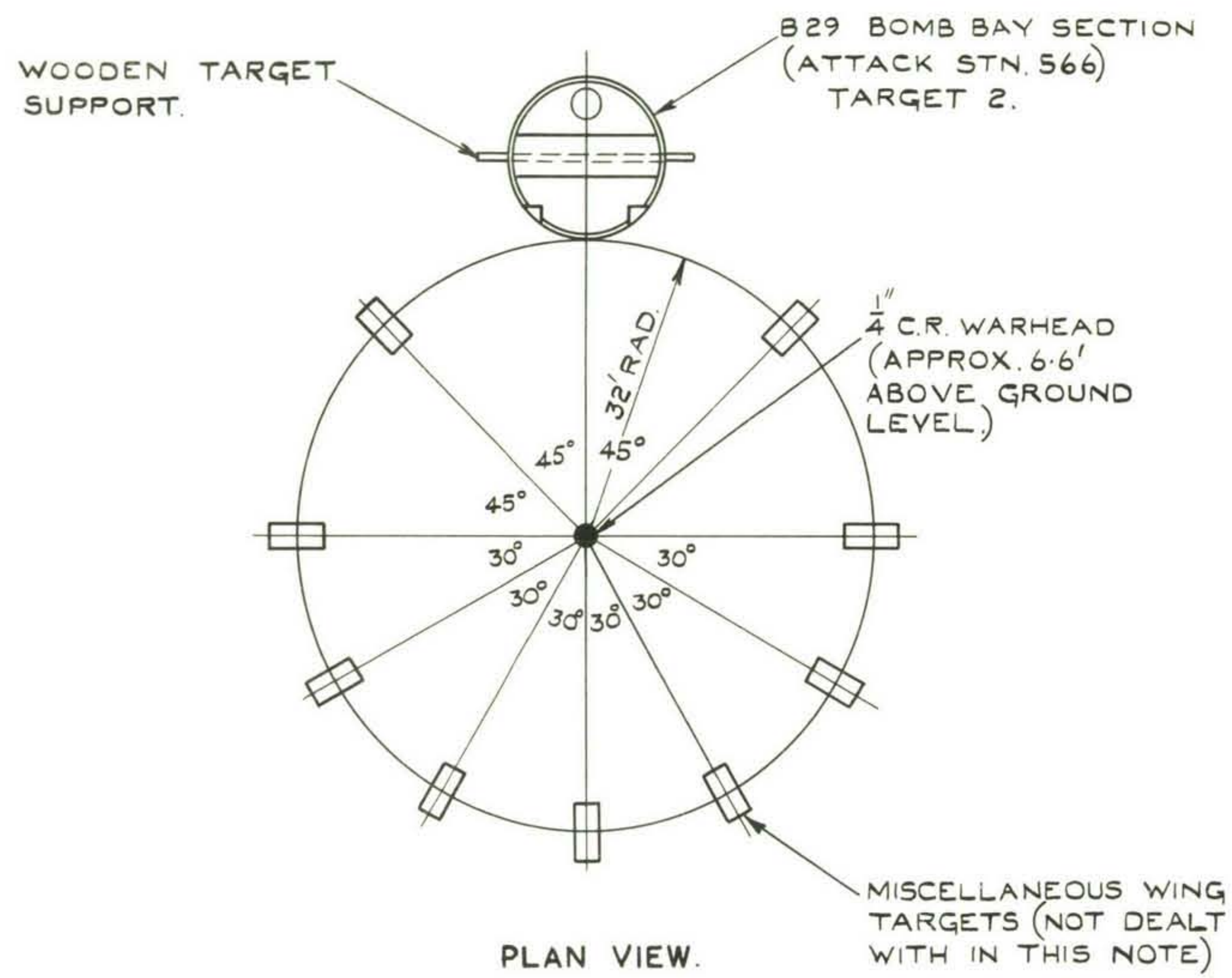

FIG. 2. TARGET LAYOUT IN FIRING 2.
SCALE: 1/240.

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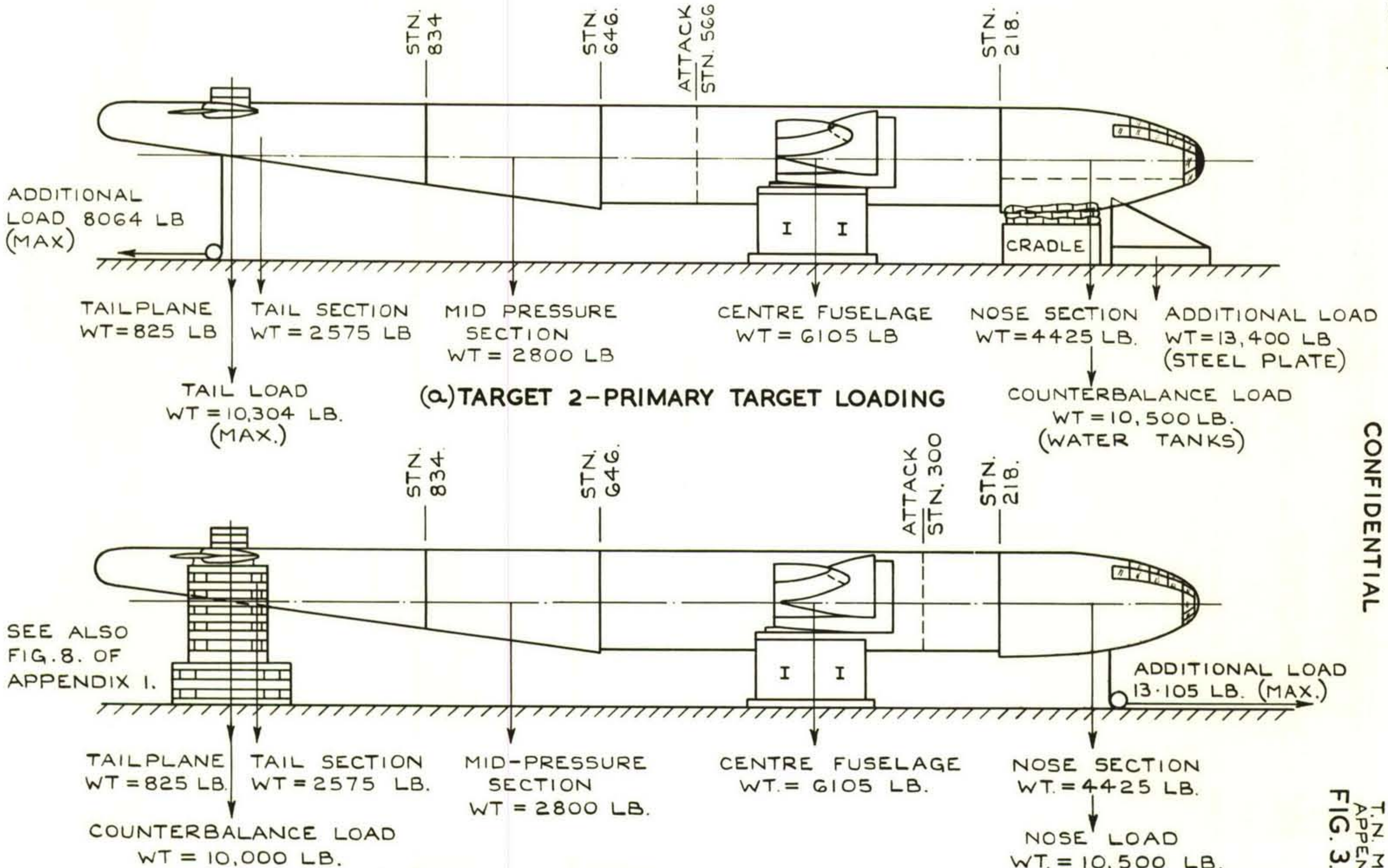

(a) TARGET 2 – PRIMARY TARGET LOADING

(b) TARGET 3B – SECONDARY TARGET LOADING

FIG. 3.(a & b) METHODS OF SUBSEQUENT LOADING OF TARGETS 2 & 3.B (SCALE – 1/144)

S.M.E. 88697/R

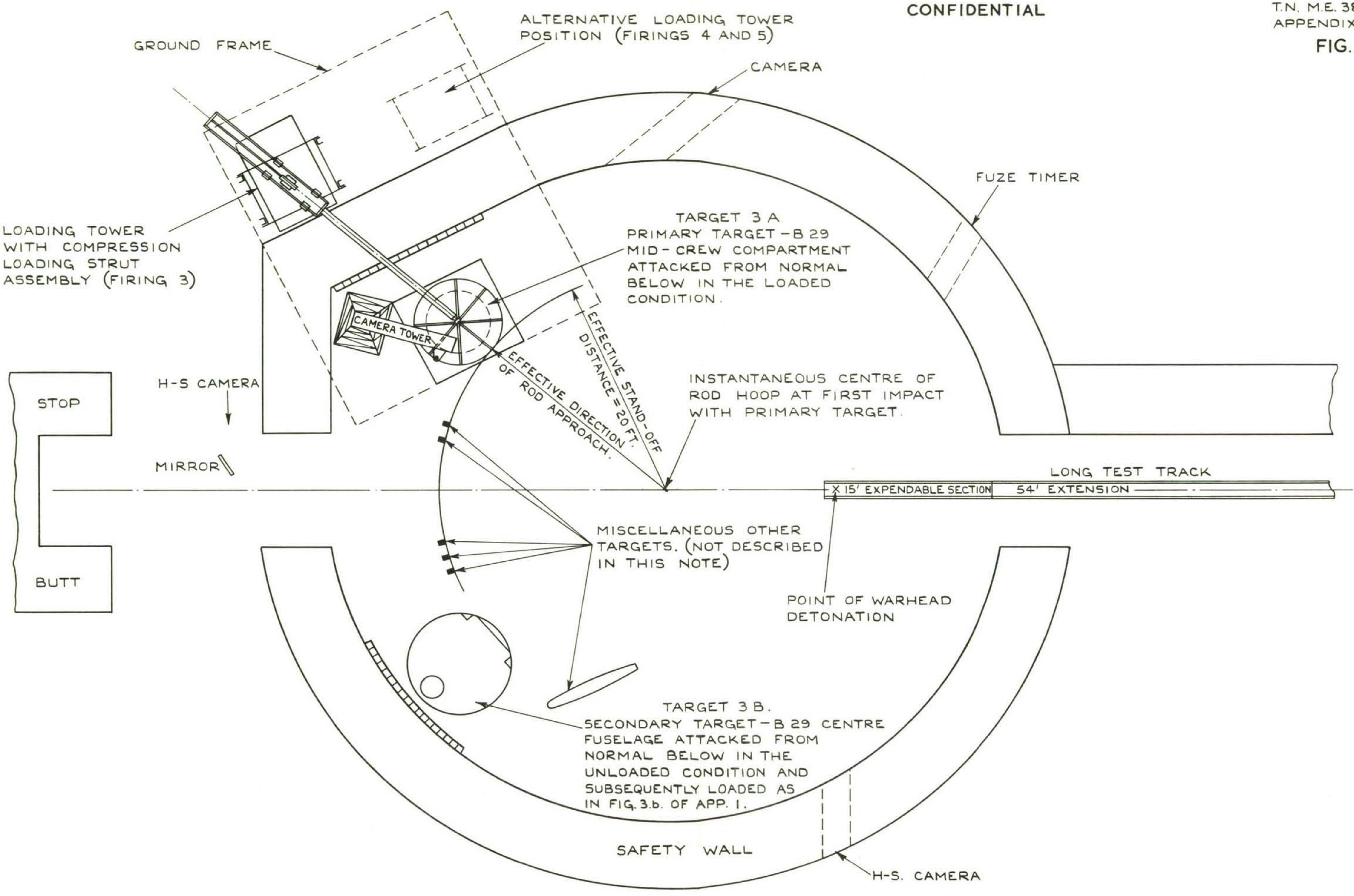

FIG. 4. TARGET LAYOUT AND PRIMARY TARGET LOADING SYSTEM USED IN DYNAMIC ROD FIRING No. 3.
(SIMILAR ARRANGEMENT USED IN FIRINGS 4 & 5) (SCALE - $1/8'' = 1'$)

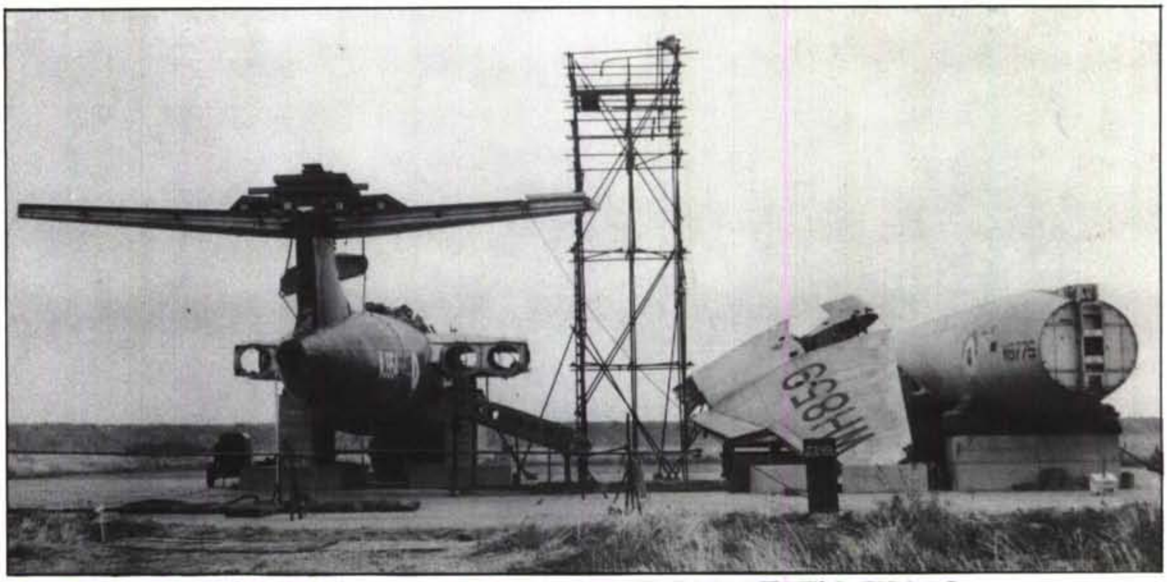

FIG.5a. OF APPENDIX I. TARGET LAYOUT FOR STATIC FIRING AGAINST LOADED AND UNLOADED TARGETS (FIRING I.)

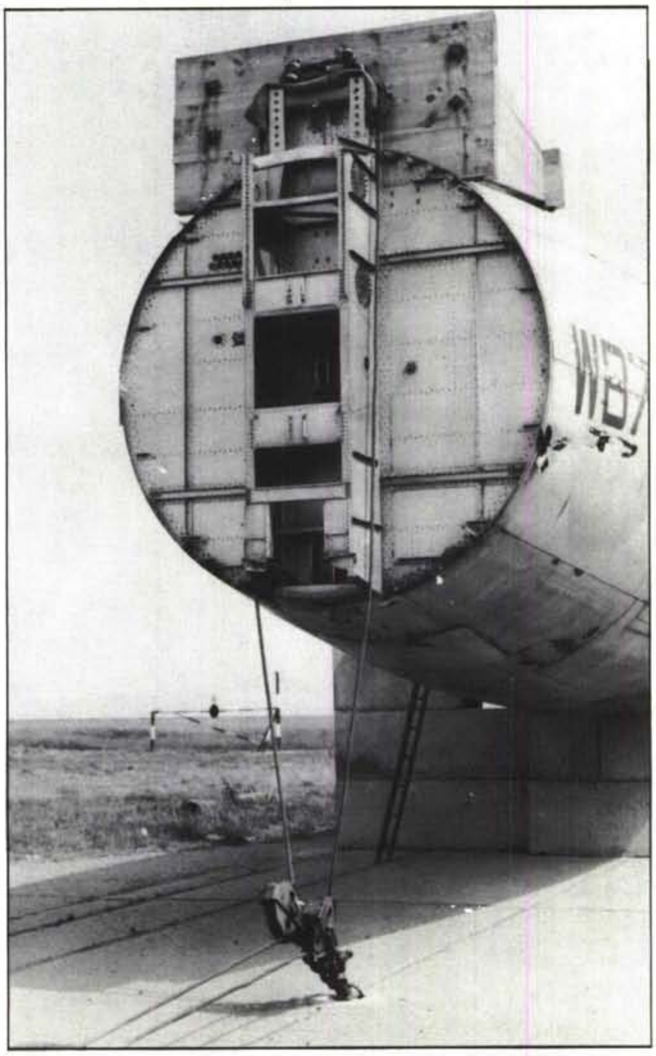

FIG.5b. OF APPENDIX I. METHOD OF SUBSEQUENTLY LOADING VICTOR TARGET I.b.

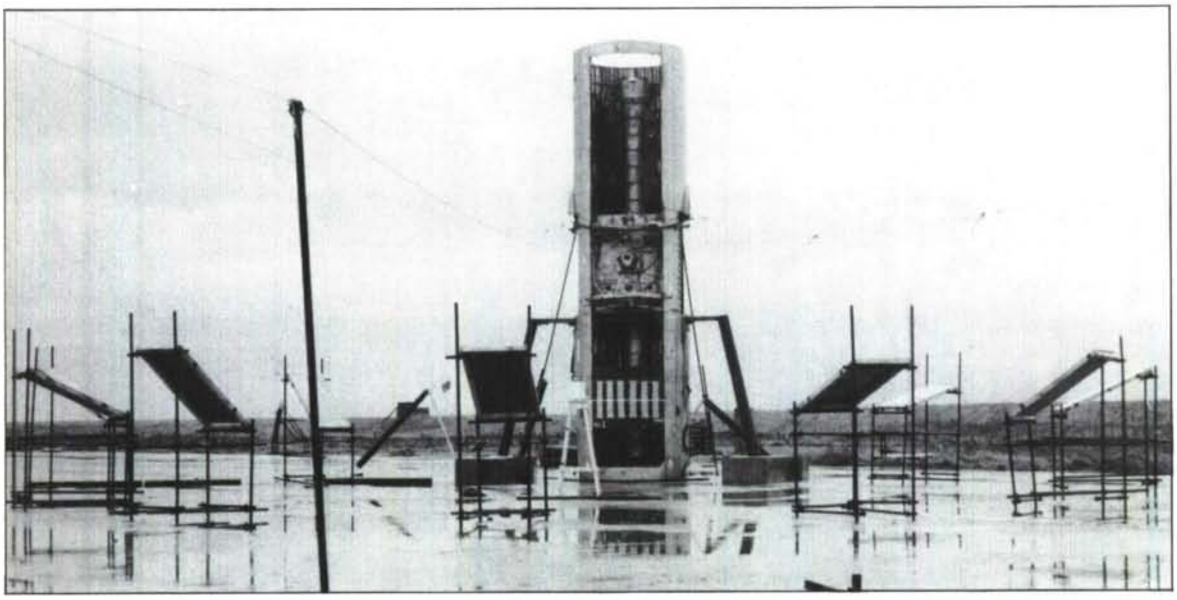

FIG.6a. OF APPENDIX I. TARGET LAYOUT FOR STATIC FIRING AGAINST UNLOADED TARGETS (FIRING 2.)

FIG.6b. OF APPENDIX I. METHOD OF SUBSEQUENTLY LOADING B29 FUSELAGE TARGET (FIRING 2.)

R.A.E. 164037 63

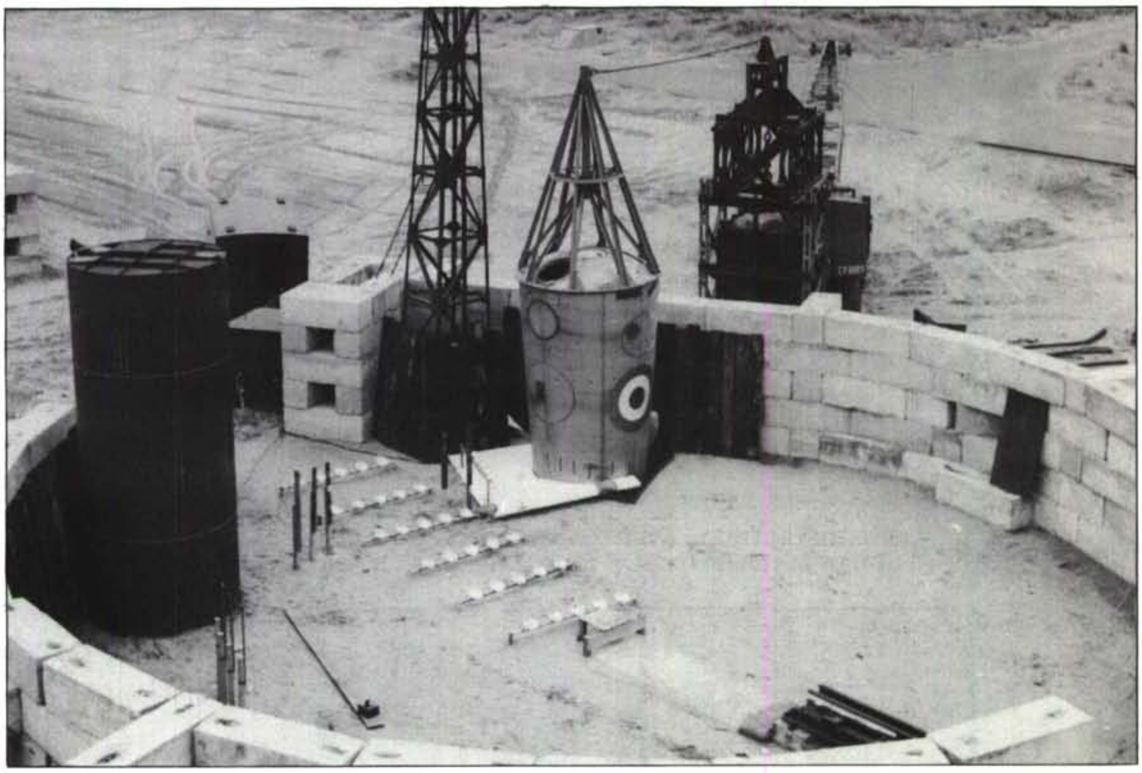

FIG.7a. OF APPENDIX I. TYPICAL TARGET LAYOUT FOR DYNAMIC WARHEAD FIRING SHOWING TARGET 4a. TENSION LOADING GEAR (FIRING 4.)

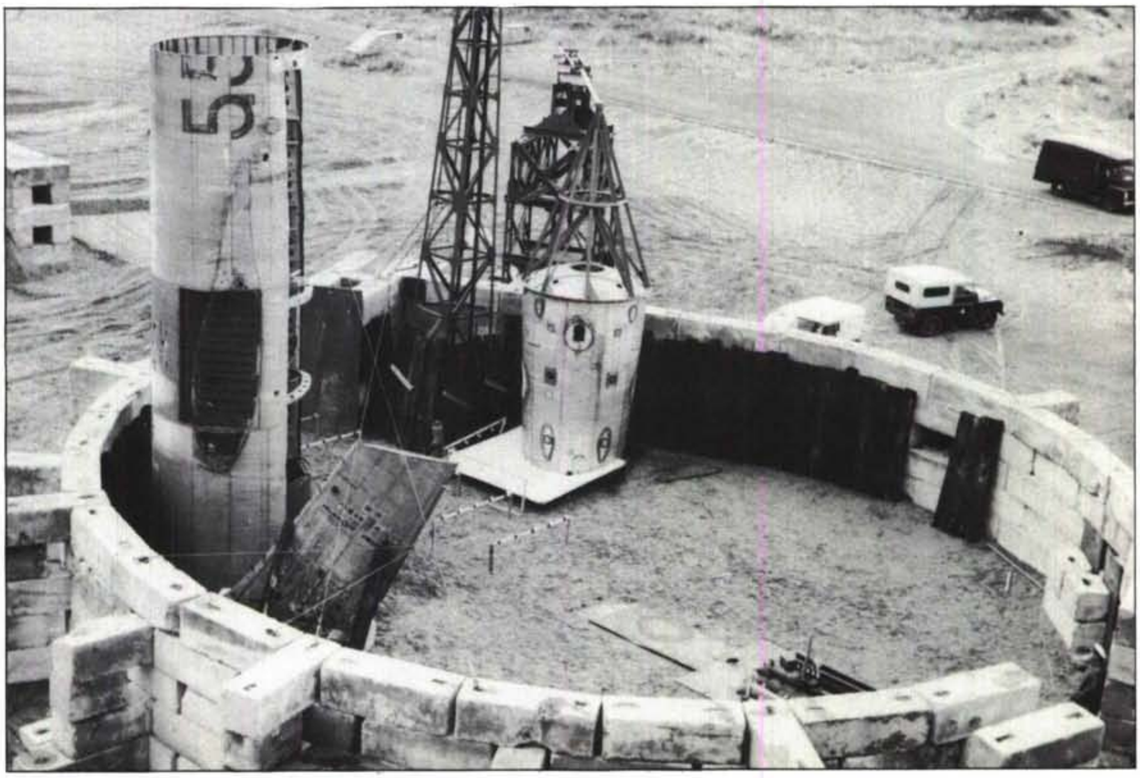

FIG.7b. OF APPENDIX I. TYPICAL TARGET LAYOUT FOR DYNAMIC WARHEAD FIRING SHOWING TARGET 3a. COMPRESSION LOADING GEAR (FIRING 3.)

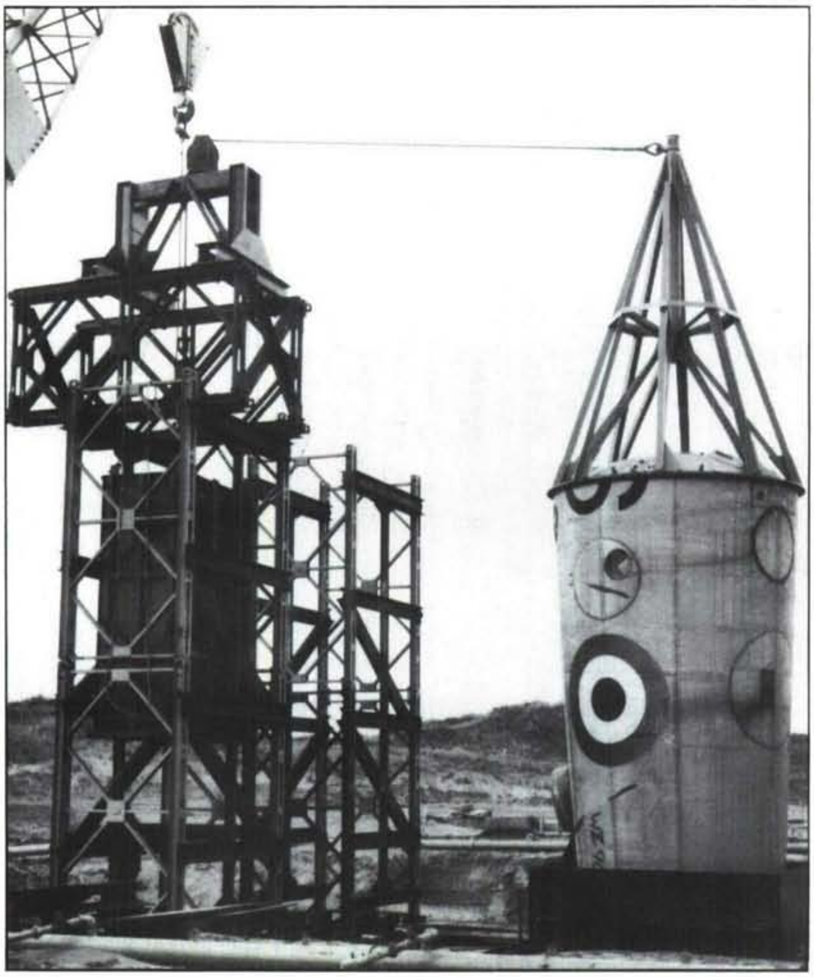

FIG.7c. OF APPENDIX I. DETAILS OF TYPICAL TARGET TENSION LOADING SYSTEM FOR DYNAMIC WARHEAD FIRINGS (TARGETS 4a. AND 5a.)

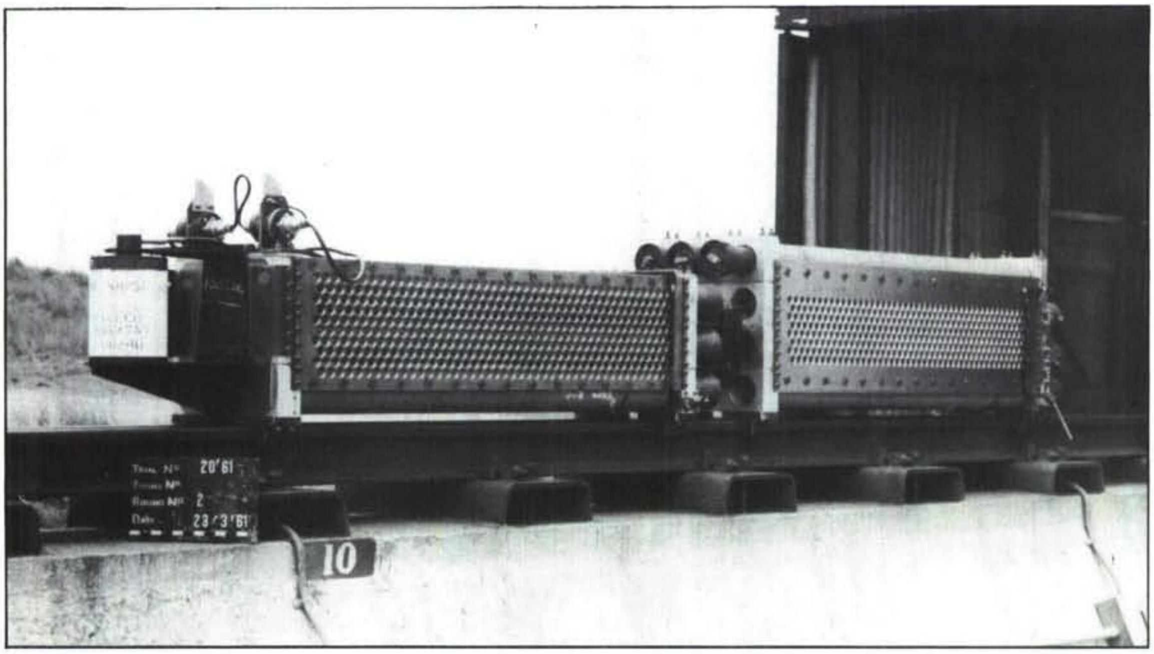

FIG.7d. OF APPENDIX I. $\frac{3}{16}$in. BLUE JAY ROD WARHEAD MOUNTED ON 2-STAGE ROCKET VEHICLE FOR DYNAMIC WARHEAD FIRING

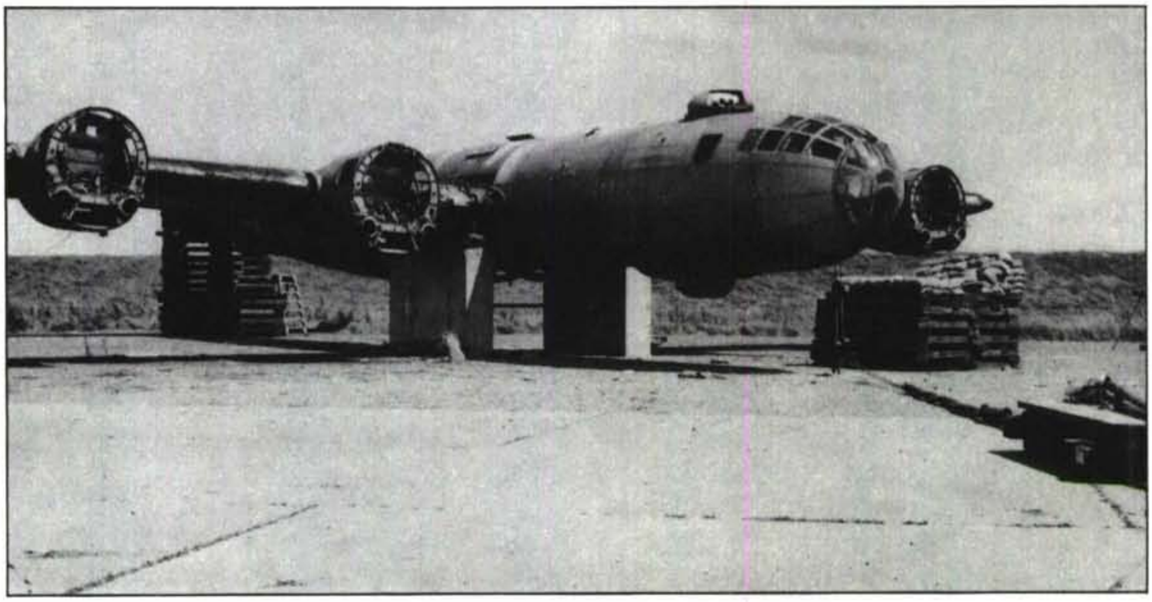

FIG.8a. OF APPENDIX I. METHOD OF SUBSEQUENTLY LOADING B29 FUSELAGE TARGET (TARGET 3b.)

FIG.8b. OF APPENDIX I. DETAIL OF TAIL SUPPORT AND COUNTERBALANCE LOADING (TARGET 3b.)

R.A.E.: 164040 63

APPENDIX 2

STRESS ANALYSIS OF DAMAGED FUSELAGE TARGETS

1 METHOD OF ANALYSIS

1.1 As a continuation of the investigation commenced in Ref.3 of the Note, simple bending stress analyses have been made of the seven damaged fuselage sections which were loaded during or subsequent to attack. The limitations and assumptions to which the analyses are subject have already been described in para 9 of the Note. The method of analysis may be briefly described as follows:-

(a) In each analysis the location of the apparent neutral axis of the damaged section was first determined.

(b) The total effective cross-sectional area of the remaining structure was then calculated and used to locate the effective neutral axis.

(c) The total moment of inertia was then determined and substituted in the relation:-

$$\sigma = \frac{My}{I}$$

where σ = apparent maximum stress (lb/in^2)
M = bending moment (lb in.)
y = distance from effective neutral axis (in.)
I = moment of inertia of section (in^4)

By this means, the magnitude and location of the apparent maximum stresses in the damaged section were determined. The detailed calculations are given in Tables 1 - 7 of this Appendix. The maximum stresses at the various loading conditions, such as level flight, failure or maximum applied, are given for the purposes of comparison.

ATTACHED:-

Tables 1 - 7

TABLE 1

Stress analysis of damaged 'Valiant' fuselage section (Stn.963)

Target No.1A – $\frac{1}{4}$ in. rod, low velocity.
(Bending-loads only, rod exit damage neglected)

Member (see Figs.1a and 3)	Distance of member from neutral axis in.	Effective skin area: Tension in^2	Effective skin area: Compression in^2	Effective stringer area in^2	Total area in^2	in^3	Distance of member from effective neutral axis in.	Moment of inertia in^4	Maximum stress ('1g' loading) lb/in^2	Maximum stress (trial loading) lb/in^2	Maximum stress applied lb/in^2
1	2	3	4	5	6	7	8	9	10	11	12
–	dy	–	–	–	A = (3) or (4) + (6)	Ady = (2) × (6)	Y = (2) − $\bar{y}$	$I = \Sigma AY^2$ = (6) × $(8)^2$	$\sigma = \frac{MY}{I}$ $\sigma = \frac{M \times (8)}{\Sigma(9)}$	$\sigma' = \frac{M'Y}{I}$ $\sigma' = \frac{M' \times (8)}{\Sigma(9)}$	$\sigma'' = \frac{M''Y}{I}$ $\sigma'' = \frac{M'' \times (8)}{\Sigma(9)}$
10	65.9	0.163		0.122	0.285	Not required (see Note (2))	65.9	1238	+28,400	+28,800	Not applicable – target failed on attack
11	63.8	0.163		0.122	0.285		63.8	1160			
12	61.5	0.163		0.122	0.285		61.5	1078			
13	59.1	0.163		0.122	0.285		59.1	996			
14	56.6	0.163		0.122	0.285		56.6	913			
15	53.9	0.163		0.122	0.285		53.9	828			
16	50.4	0.163		0.301	0.464		50.4	1179			
17	47.0	0.163		0.128	0.291		47.0	643			
18	43.9	0.163		0.128	0.291		43.9	561			
19	40.7	0.163		0.128	0.291		40.7	482			
20	37.6	0.163		0.128	0.291		37.6	412			
21	34.3	0.163		0.128	0.291		34.3	343			
22	30.9	0.163		0.128	0.291		30.9	278			
23-23'	27.6	0.326		0.256	0.582		27.6	444			
24-24'	24.3	0.326		0.256	0.582		24.3	344			
25-25'	20.9	0.326		0.256	0.582		20.9	254			
26-26'	17.5	0.326		0.256	0.582		17.5	178			
27-27'	13.4	0.350		0.602	0.952		13.4	171			
28-28'	9.7	0.372		0.256	0.628		9.7	59			
29-29'	6.9	0.368		0.256	0.624		6.9	30			
30	4.1	0.184		0.128	0.312		4.1	5			
31	1.4	0.184		0.128	0.312		1.4	0.6			
32	−1.2		0.184	0.128	0.312		−1.2	0.5			
33	−3.9		0.184	0.173	0.357		−3.9	5.4			
34-34'	−6.4		0.368	0.346	0.714		−6.4	29			
35-35'	−8.9		0.368	0.346	0.714		−8.9	56			
36-36'	−11.4		0.368	0.346	0.714		−11.4	93			
37-37'	−13.7		0.368	0.346	0.714		−13.7	134			
38-38'	−16.0		0.368	0.346	0.714		−16.0	183			
39-39'	−18.1		0.372	0.346	0.718		−18.1	236			
40-40'	−20.2		0.263	0.346	0.609		−20.2	249			
41-41'	−22.8		0.218	9.200	9.418		−22.8	4897	−9,850	−10,000	
Σ								17479.5			

(1) Distance from neutral axis to datum = −20.3 in.

(2) $\bar{y}$ = 0 (since skin in compression is assumed 100% effective under '1g' loads)

(3) Aircraft '1g' bending moment M' = 7,539,000 lb in.

(4) Trials bending moment M" = 7,660,000 lb in.

TABLE 2

Stress analysis of damaged 'Victor' fuselage section (Stn.740)

Target No.1B - $\frac{1}{4}$ in. rod low velocity
(Bending loads only, rod exit damage neglected)

Member (see Figs.1b and 4)	Distance of member from neutral axis in.	Effective skin area		Effective stringer area in^2	Total area in^2	in^3	Distance of member from effective neutral axis in.	Moment of inertia in^4	Maximum stress ('1g' loading) lb/in^2	Maximum stress (trial loading) lb/in^2	Maximum stress applied lb/in^2
		Tension in^2	Compression in^2								
1	2	3	4	5	6	7	8	9	10	11	12
-	dy	-	-	-	A = (3) or (4) + (5)	A.dy = (2) × (6)	Y = (2) - $\bar{y}$	$I = \Sigma AY^2$ = $(6) \times (8)^2$	$\sigma = \frac{MY}{I}$ $\sigma = \frac{M \times (8)}{\Sigma(9)}$	$\sigma' = \frac{M'Y}{I}$ $\sigma' = \frac{M' \times (8)}{\Sigma(9)}$	$\sigma'' = \frac{M''Y}{I}$ $\sigma'' = \frac{M'' \times (8)}{\Sigma(9)}$
8	54.3	0.238		0.177	0.415	Not required - see note (2).	54.3	1223	+20,300	None	+19,100
9	50.4	0.238		0.177	0.415		50.4	1054			
10	45.9	0.293		0.177	0.470		45.9	990			
11	41.1	0.305		0.201	0.506		41.1	855			
12	35.9	0.202		0.177	0.379		35.9	489			
13	33.1	0.193		0.177	0.370		33.1	406			
14	30.3	0.045		0.177	0.222		30.3	204			
15	27.4	0.193		0.177	0.370		27.4	278			
16	24.5	0.045		0.177	0.222		24.5	133			
17	21.5	0.193		0.177	0.370		21.5	171			
18	18.4	0.045		0.177	0.222		18.4	75			
19	15.3	0.193		0.177	0.370		15.3	87			
20	12.2	0.045		0.177	0.222		12.2	33			
21	9.1	0.193		0.177	0.370		9.1	31			
22	6.0	0.045		0.218	0.263		6.0	10			
23	2.9	0.193		0.102	0.295		2.9	3			
24	-0.2		0.045	0.177	0.222		-0.2	0			
25	-3.3		0.193	0.102	0.295		-3.3	3			
26	-6.4		0.045	0.177	0.222		-6.4	9			
27	-9.5		0.193	0.102	0.295		-9.5	27			
28	-12.5		0.045	0.177	0.222		-12.5	35			
29	-15.4		0.193	0.102	0.295		-15.4	70			
30	-18.3		0.023	0.218	0.241		-18.3	81			
31-31'	-22.3		-	11.400	11.400		-22.3	5666	-8,350	None	-7,850
32	+40.0		-	0.831	0.831		+40.0	1330			
33-10% of 33'	+36.5		-	1.003	1.003		+36.5	1336			
34-25% of 34'	+36.5		-	1.140	1.140		+36.5	1521			
Σ					21.647			16,120			

(1) Distance from neutral axis to datum = -6.0 in.

(2) $\bar{y}$ = 0 (since skin in compression is assumed 100% effective under '1g' loads)

(3) Aircraft '1g' bending moment M = 6,040,000 lb in.

(4) Trials bending moment M' = None

(5) Failing bending moment M" = 5,680,000 lb in.

TABLE 3

Stress analysis of damaged B.29 fuselage section (Stn.566)

Target No.2 - $\frac{1}{4}$ in. rod low velocity
(Bending loads only, rod exit damage neglected)

Member (see Figs.2c and 8)	Distance of member from neutral axis in.	Effective skin area: Tension in^2	Effective skin area: Compression in^2	Effective stringer area in^2	Total area in^2	in^3	Distance of member from effective neutral axis in.	Moment of inertia in^4	Maximum stress ('1g' loading) lb/in^2	Maximum stress (trial loading) lb/in^2	Maximum stress applied lb/in^2
1	2	3	4	5	6	7	8	9	10	11	12
-	dy	-	-	-	A = (3) or (4) + (5)	A.dy = (2) × (6)	Y = (2) - $\bar{y}$	$I = \Sigma AY^2$ = $(6) \times (8)^2$	$\sigma = \frac{MY}{I}$ $\sigma = \frac{M \times (8)}{\Sigma(9)}$	$\sigma' = \frac{M'Y}{I}$ $\sigma' = \frac{M' \times (8)}{\Sigma(9)}$	$\sigma'' = \frac{M''Y}{I}$ $\sigma'' = \frac{M'' \times (8)}{\Sigma(9)}$
A	45.3	0.451	-	0.402	0.853	38.7	42.9	1573	+6,920	+6.920	+16,200
B-B'	44.6	2x0.451	-	2x0.395	1.692	75.5	42.2	3020			
C-C'	42.6	2x0.451	-	2x0.395	1.692	72.0	40.2	2733			
D-D'	39.2	2x0.451	-	2x0.198	1.298	50.8	36.8	1758			
E-E'	37.0	-	-	2x0.122	0.244	9.0	34.6	293			
F-F'	34.6	2x0.451	-	2x0.395	1.692	58.5	32.2	753			
G-G'	28.8	2x0.451	-	2x0.122	1.146	33.0	26.4	800			
H-H'	22.1	2x0.451	-	2x0.301	1.504	33.2	19.7	586			
I-I'	14.6	2x0.451	-	2x0.122	1.146	16.7	12.2	171			
J-J'	6.3	2x0.451	-	2x0.301	1.504	9.5	3.9	23			
K-K'	-2.2	0.451	0.077	2x0.173	0.874	-1.9	-4.6	18			
L-L'	-11.0	-	2x0.077	2x0.173	0.500	-5.5	-13.4	89			
M-50% of M'	-19.8	-	0.077	$1\frac{1}{2}$x0.301	0.529	-10.5	-22.2	263			
N	-28.3	-	-	0.173	0.173	-4.9	-30.7	163			
50% of O-50% of O'	-36.6	-	-	0.173	0.173	-6.3	-39.0	262			
P-25% of P'	-40.3	-	-	$1\frac{1}{4}$x0.732	0.915	-36.9	-42.7	1667			
R-R'	-40.3	-	-	2x0.940	1.880	-75.8	-42.7	3425			
T-50% of T'	-53.7	-	-	$1\frac{1}{2}$x2.534	3.801	-204.0	-56.1	11950	-9,040	-9,040	-21,200
Σ					21.616	+51.1		29,547			

(1) Distance from neutral axis to datum = +11 in.

(2) $\bar{y} = \frac{\Sigma(7)}{\Sigma(6)} = \frac{51.1}{21.616} = +2.4$ in.

(3) Aircraft '1g' bending moment M = 4,763,000 lb in.

(4) Trials bending moment M' = 4,763,000 lb in.

(5) Maximum applied bending moment M" = 11,160,000 lb in.

TABLE 4

Stress analysis of damaged B.29 fuselage section (Stn.300)

Target No.3B - 3/16 in. rod high velocity
(Bending loads only, rod exit damage neglected)

Member (see Figs.2a and 9)	Distance of member from neutral axis in.	Effective skin area: Tension in^2	Effective skin area: Compression in^2	Effective stringer area in^2	Total area in^2	in^3	Distance of member from effective nuetral axis in.	Moment of inertia in^4	Maximum stress ('1g' loading) lb/in^2	Maximum stress (trial loading) lb/in^2	Maximum stress applied (2.8g loading) lb/in^2
1	2	3	4	5	6	7	8	9	10	11	12
-	dy	-	-	-	A = (3) or (4) + (5)	A.dy = (2) × (6)	Y = (2) - $\bar{y}$	$I = \Sigma AY^2$ = $(6) \times (8)^2$	$\sigma = \frac{MY}{I}$ $\sigma = \frac{M \times (8)}{\Sigma(9)}$	$\sigma' = \frac{M'Y}{I}$ $\sigma' \frac{M' \times (8)}{\Sigma(9)}$	$\sigma'' = \frac{M''Y}{I}$ $\sigma'' \frac{M'' \times (8)}{\Sigma(9)}$
A	36.2	0.358		0.402	0.760	27.5	30.4	702	4,525	4,525	12,840
B-B'	35.5	2x0.358		2x0.395	1.506	53.4	29.7	1328			
C-C'	33.4	2x0.358		2x0.395	1.506	50.3	27.6	1148			
D-D'	30.0	2x0.358		2x0.198	1.112	33.4	24.2	652			
E-E'	27.7	-		2x0.122	0.244	6.7	21.9	117			
F-F'	25.3	2x0.408		2x0.395	1.606	40.6	19.5	610			
G-G'	19.5	2x0.457		2x0.122	1.158	22.6	13.7	218			
H-H'	12.7	2x0.457		2x0.301	1.516	19.2	6.9	72			
I-I'	5.1	2x0.457		2x0.122	1.158	5.9	0.7	0			
J-J'	-3.2		2x0.078	2x0.301	0.758	-2.4	-9.0	61			
K-K'	-11.9		2x0.078	2x0.173	0.502	-6.0	-17.7	157			
L	-20.8		0.078	0.173	0.251	-5.2	-26.6	178			
M	-29.7		0.114	0.301	0.415	-12.3	-35.5	523			
N	-38.4		0.078	0.173	0.251	-9.6	-44.2	490			
O	-46.7		0.078	0.173	0.251	-11.7	-52.5	692			
P	-49.2		0.126	0.732	0.858	-42.2	-55.0	2595			
Q	-54.3		0.078	0.395	0.473	-25.7	-60.1	1708			
R	-49.2		0.172	0.940	1.112	-54.7	-55.0	3364	-8,180	-8,189	-23,200
Σ					15.437	+89.8		14615			

(1) Distance from neutral aixs to datum = +20.8 in.

(2) $\bar{y} = \frac{\Sigma(7)}{\Sigma(6)} = \frac{89.8}{15.437} = +5.8$ in.

(3) Aircraft '1g' bending moment M = 2,174,400 lb in.

(4) Trials bending moment M' = 2,174,400 lb in.

(5) Maximum applied bending moment M" = 6,175,700 lb in.

TABLE 5

Stress analysis of damaged B.29 fuselage section (Stn.768)

Target No.3A - 3/16 in. rod high velocity
(Bending loads only, rod exit damage neglected)

Member (see Figs.2b and 10)	Distance of member from neutral axis in.	Effective skin area: Tension in^2	Effective skin area: Compression in^2	Effective stringer area in^2	Total area in^2	in^3	Distance of member from effective neutral axis in.	Moment of inertia in^4	Maximum stress ('1g' loading) lb/in^2	Maximum stress (trial loading) lb/in^2	Maximum stress applied lb/in^2
1	2	3	4	5	6	7	8	9	10	11	12
-	dy	-	-	-	A = (3) or (4) + (5)	A.dy = (2) × (6)	Y = (2) - $\bar{y}$	$I = \Sigma AY^2$ = (6) × $(8)^2$	$\sigma = \frac{MY}{I}$ $\sigma = \frac{M \times (8)}{\Sigma(9)}$	$\sigma' = \frac{M'Y}{I}$ $\sigma' = \frac{M' \times (8)}{\Sigma(9)}$	$\sigma'' = \frac{M''Y}{I}$ $\sigma'' = \frac{M'' \times (8)}{\Sigma(9)}$
A	36.1	0.378		0.402	0.780	28.2	33.3	865	+4,710	+4,925	+9,570
B-B'	35.5	2x0.378		0.346	1.102	39.1	32.7	1180			
C-C'	34.7	-		0.244	0.244	8.5	31.9	248			
D-D'	33.8	2x0.378		0.346	1.102	37.3	31.0	1059			
E-E'	32.4	-		0.244	0.244	7.9	29.6	214			
F-F'	31.0	2x0.378		0.346	1.102	34.2	28.2	878			
G-G'	28.9	-		0.244	0.244	7.1	26.1	166			
H-H'	27.1	2x0.378		0.790	1.546	41.9	24.3	913			
I-I'	22.3	2x0.378		0.244	1.000	22.3	19.5	380			
J-J'	16.3	2x0.337		0.804	1.478	24.1	13.5	269			
K-K'	10.3	0.297	0.048	0.244	0.589	6.1	7.5	33			
L-L'	4.3		2x0.048	0.602	0.698	3.0	1.5	1.6			
M-M'	-3.9		2x0.048	0.346	0.442	-1.7	-6.7	19.8			
N	-11.1		0.076	0.279	0.355	-3.9	-13.9	68.6			
O	-18.5		0.048	0.301	0.349	-6.5	-21.3	158			
P	-25.7		0.048	0.173	0.221	-5.7	-28.5	180			
Q	-32.5		0.048	0.395	0.443	-14.4	-35.3	551			
R	-38.8		0.144	0.402	0.546	-21.2	-41.6	945			
S-90% of S'	-44.5		0.091	2.808	2.899	-129.0	-47.3	6485			
T	-47.0		0.048	0.173	0.221	-10.4	-49.8	549			
U	-49.3		0.048	0.395	0.443	-21.8	-52.1	1202	-7,365	-7,710	-14,950
Σ					16.048	+45.1		16370			

(1) Distance from neutral axis to datum = 11.1 in.

(2) $\bar{y} = \frac{\Sigma(7)}{\Sigma(6)} = \frac{45.1}{16.048} = +2.8$ in.

(3) Aircraft '1g' bending moment M = 2,314,000 lb in.

(4) Trials bending moment M' = 2,420,000 lb in.

(5) Maximum applied bending moment M" = 4,700,000 lb in.

TABLE 6

Stress analysis of damaged B.29 fuselage section (Stn.768)

Target No.4A – 3/16 in. rod high velocity
(Bending loads only, rod exit damage neglected)

Member (see Figs.2b and 11)	Distance of member from neutral axis in.	Effective skin area: Tension in^2	Effective skin area: Compression in^2	Effective stringer area in^2	Total area in^2	in^3	Distance of member from effective neutral axis in.	Moment of inertia in^4	Maximum stress ('1g' loading) lb/in^2	Maximum stress (trial loading) lb/in^2	Maximum stress applied lb/in^2
1	2	3	4	5	6	7	8	9	10	11	12
-	dy	-	-	-	A = (3) or (4) + (5)	A.dy = (2) × (6)	Y = (2) − $\bar{y}$	$I = \Sigma AY^2$ = $(6) \times (8)^2$	$\sigma = \frac{MY}{I}$ $\sigma = \frac{M \times (8)}{\Sigma(9)}$	$\sigma' = \frac{M'Y}{I}$ $\sigma' = \frac{M' \times (8)}{\Sigma(9)}$	$\sigma'' = \frac{M''Y}{I}$ $\sigma'' = \frac{M'' \times (8)}{\Sigma(9)}$
D	61.2	0.378		0.173	0.551	33.7	57.0	1790	+9,060	None	+19,550
F	58.4	0.378		0.173	0.551	32.2	54.2	1619			
G	56.3	-		0.122	0.122	6.9	52.1	331			
H	54.5	0.378		0.395	0.773	42.1	50.3	1956			
I	49.7	0.378		0.122	0.500	24.9	45.5	1035			
J	43.7	0.337		0.402	0.739	32.3	39.5	1252			
K	37.7	0.297		0.122	0.419	15.8	33.5	470			
L	30.9	0.297		0.301	0.598	18.5	26.7	426			
M	23.7	0.297		0.173	0.470	11.1	19.5	179			
N	16.3	0.297		0.279	0.576	9.4	12.1	84			
O	8.9	0.297		0.301	0.598	5.3	4.7	13			
P	1.7	0.228	0.008	0.173	0.409	0.7	-2.5	2			
Q	-5.1		0.048	0.395	0.443	-2.3	-9.3	39			
R	-11.4		0.144	0.402	0.546	-6.2	-15.6	133			
S-S'	-17.1		2x0.048	2x1.478	3.052	-52.2	-21.3	1384			
T-T'	-19.6		2x0.048	2x0.173	0.442	-8.7	-23.8	250			
U-U'	-21.9		2x0.048	2x0.395	0.886	-19.4	-26.1	603			
V-V'	-25.8		2x0.122	2x0.402	1.048	-27.0	-30.0	943			
W-W'	-28.6		2x0.031	2x0.395	0.852	-24.4	-32.8	917			
X-X'	-30.3		2x0.031	2x0.173	0.408	-12.4	-34.5	486			
Y	-30.9		0.200	0.402	0.602	-18.6	-35.1	742	-5,590	None	-12,000
Σ					14.585	+61.7		14554			

(1) Distance from neutral axis to datum = -16.3 in.

(2) $\bar{y} = \frac{\Sigma(7)}{\Sigma(6)} = \frac{61.7}{14.6} = +4.2$ in.

(3) Aircraft '1g' bending moment M = 2,314,000 lb in.

(4) Trials bending moment M' = None

(5) Maximum applied bending moment M" = 4,980,000 lb in.

NOTE: Stringers 'C' and 'E' not present in this target

TABLE 7

Stress analysis of damaged B.29 fuselage section (Stn.768)

Target No.5A - 3/16 in. rod, high velocity
(Bending loads only, rod exit damage neglected)

Member (see Figs.2b and 12)	Distance of member from neutral axis in.	Effective skin area: Tension in^2	Effective skin area: Compression in^2	Effective stringer area in^2	Total area in^2	in^3	Distance of member from effective neutral axis in.	Moment of inertia in^4	Maximum stress ('1g' loading) lb/in^2	Maximum stress (trial loading) lb/in^2	Maximum stress applied lb/in^2
1	2	3	4	5	6	7	8	9	10	11	12
-	dy	-	-	-	A $= (3)$ or $(4) + (5)$	A.dy $= (2) \times (6)$	Y $= (2) - \bar{y}$	$I = \Sigma AY^2$ $= (6) \times (8)^2$	$\sigma = \frac{MY}{I}$ $\sigma = \frac{M \times (8)}{\Sigma(9)}$	$\sigma' = \frac{M'Y}{I}$ $\sigma' = \frac{M' \times (8)}{\Sigma(9)}$	$\sigma'' = \frac{M''Y}{I}$ $\sigma'' = \frac{M'' \times (8)}{\Sigma(9)}$
D	61.7	0.378		0.173	0.551	33.9	57.5	1820	+9,040	+9,740	+16,450
F	58.9	0.378		0.173	0.551	32.5	54.7	1647			
G	56.8	-		0.122	0.122	6.9	52.6	337			
H	55.0	0.378		0.395	0.773	42.5	50.8	1995			
I	50.2	0.378		0.122	0.500	25.1	46.0	1057			
J	44.2	0.337		0.402	0.739	32.7	40.0	1182			
K	38.2	0.297		0.122	0.419	16.0	34.0	484			
L	31.4	0.297		0.301	0.598	18.8	27.2	443			
M	24.2	0.297		0.173	0.470	11.4	20.0	228			
N	16.8	0.297		0.279	0.576	9.7	12.6	92			
O	9.4	0.297		0.301	0.598	5.6	5.2	16			
P	2.2	0.240	0.006	0.173	0.419	0.9	-2.0	2			
Q	-4.6		0.043	0.395	0.443	-2.0	-8.8	34			
R-R'	-10.9		2x0.144	2x0.402	1.092	-11.9	-15.1	249			
S-S'	-16.6		2x0.048	2x1.478	3.052	-50.7	-20.8	1318			
T-T'	-19.1		2x0.048	2x0.173	0.442	-8.4	-23.3	239			
U-U'	-21.4		2x0.048	2x0.395	0.886	-18.9	-25.6	581			
V-V'	-25.3		2x0.122	2x0.402	1.048	-26.5	-29.5	912			
W-W'	-28.1		2x0.031	2x0.395	0.852	-23.9	-32.3	888			
X-X'	-29.8		2x0.031	2x0.173	0.408	-12.2	-34.0	471			
Y	-30.4		0.200	0.402	0.602	-18.3	-34.6	720	-5,440	-5,870	-9,900
Σ					15.141	+63.2		14,715			

(1) Distance from neutral axis to datum = -16.8 in.

(2) $\bar{y} = \frac{\Sigma(7)}{\Sigma(6)} = \frac{63.2}{15.14} = +4.2$ in.

(3) Aircraft '1g' bending moment M = 2,314,000 lb in.

(4) Trials bending moment M' = 2,495,000 lb in.

(5) Failing bending moment M" = 4,210,000 lb in.

NOTE: Stringers 'C' and 'E' not present in this target

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Royal Aircraft Establishment

THE ATTACK OF AIRCRAFT FUSELAGES BY CONTINUOUS ROD WARHEADS (3/16 and 1/4 inch square-section rods). Mallin, R.G.E. September 1963.

This Note records the results of a number of static and dynamic detonations of 3/16 and 1/4 inch square-section continuous rod (C.R.) warheads against Boeing 'B.29', Vickers 'Valiant', Handley Page 'Victor' and some replica steel fuselage sections, most of which were either loaded to simulate straight and level flight conditions during attack and/or were subsequently loaded to determine residual strength. Rod effectiveness was found to depend, for all the targets, on the direction of rod approach to, and the construction of, the section attacked but at least for the 3/16 inch C.R., appeared to be independent of rod impact velocity in the range 3000 to 5000 f.p.s.

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